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ON THE DEVELOPMENT OF THE THEORY OF THE STEAM ENGINE AND ITS APPLICATION. AN HISTORICAL OUTLINE SKETCH.

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The following paper is intended to present, in the briefest possible form, an outline of the growth of the Theory of the Steam Engine, from its first and most primitive form to its most recent and most thoroughly practical development in application. It is not proposed to make this sketch in any sense complete, and it is hardly expected that it can be critically accurate. It may, however, prove interesting, and may be of real service, it is hoped, as presenting a distinct outline of what will, when more completely worked up, prove to be an exceedingly interesting and important detail of the history of applied science.

A complete history of the development of the Theory of the Steam Engine would include, first, the history of the Mechanical Theory of Heat; secondly, the history of the Science of Thermodynamics, which has been the outgrowth of that theory; third, the history of the application of the science of heat-transformation to the case of the Steam Engine; and, fourthly, an account of the completion of the Theory of the Steam and other Heat Engines by the introduction of the theory

of losses by the more or less avoidable forms of waste, as distinguished from those necessary and unavoidable wastes indicated by the pure theory of thermodynamics. The first and second of these divisions are treated of in works on thermodynamics, and in treatises on physics. The third division is briefly considered, and usually very incompletely, in treatises on the steam engine; while the last is of too recent development to be the the subject of complete treatment, as yet, in any existing works. The principal object of the present paper is simply to collect into a condensed form, and in proper relations, these several branches of the subject, leaving for another time and place that more full and complete account which might, did opportunity offer, be prepared to-day.

The "Mechanical Theory of Heat," as is now well understood, existed, as a speculation, from the days of the earliest philosophies. The contest which raged with such intensity, and sometimes acrimony, among speculative men of science, during the last century, was merely a repetition of struggles of which we find evidences, at intervals, throughout the whole period of recorded history. The closing period of this, which proved to be an important revolution in science, marked the beginning of the nineteenth century. It was inaugurated by the introduction of experimental investigation directed toward the crucial point of the question at issue. It terminated, about the middle of the century, with the acceptance of the general results of such experiment by every scientific man of acknowledged standing, on either side the Atlantic. The doctrine that heat was material, and its transfer a real movement of substance from the source to the receiver of heat, was thus finally completely superseded by the theory, now become an ascertained truth, that heat is a form of energy, and its transformation a change in the location and method of molecular vibration. The Dynamical Theory of Heat was first given a solid basis by the experiments of Count Rumford (Benjamin Thompson), in 1796–7—of which an account was given in a paper read by Rumford before the Royal Society of Great Britain in 1798—by the experiments of Sir Humphrey Davy in 1798–9, and by the later and more precise determinations of the value of the mechanical equivalent of heat, by Joule, in 1843, and subsequently.

The Science of Thermodynamics has for its essential basis the established fact of the dynamical nature of heat, and the fact of the quantivalence of two forms of energy—heat and mechanical motion, mole-

cular energy and mass energy. Resting, as it does, on fundamental, experimentally determined, principles, it could have no existence until, during the early part of the present century, these phenomena and these truths were well investigated and firmly established. Immediately upon the settlement of the controversy relating to the nature of heat, it became possible to commence the construction of the science which, asserting the mechanical theory of heat as as its fundamental fact, and the conservation and quantivalence of the two forms of energy as its fundamental principle, led to the determination of the method and extent of the transformation of the one into the other, during any prescribed series of physical changes.

It is not within the province of this paper to examine the claims made for rival philosophers, in the debate over the matter of priority of discovery of the mutual relations of the phenomena and principles of the new science. It is sufficiently evident that the revelation of the facts of the case led many minds to study the subject, and led to its nearly contemporaneous development in several countries. The first period of the development of the science was occupied almost exclusively by the exposition of the dynamical theory of heat, which lies at the bottom of the whole. This strikingly interesting and obviously important subject so absorbed the attention and occupied the thoughts of physicists that they seem hardly to have attempted to look beyond it, as a rule, and hence failed, at first, to see into what a magnificent department of theoretical and experimental investigation they were called. Mohr, in 1837; Seguin, in 1839; Mayer, of Heilbronn, in 1842, and Colding, in 1843, each took a step into a field, the limits of which and the importance of which they could at that time hardly have imagined. Mayer certainly had a very clear conception of the bearing of the new theory of heat upon dynamics, and exhibited remarkable insight into the far-reaching principles of the new science. He collated the facts more exactly determined later by Joule and others with the principle of the conservation of energy, and applied the rudiments of a science thus constructed to the calculation of the quantity of carbon and expenditure of heat which are unavoidably needed by a mountain climber, doing a given quantity of work, in the elevation of his own body to a specified height. The work of Mayer may be taken as representing the first step in the production of a Science of Thermodynamics, and in the deduction of the consequences of the fact which had, until his time, so seldom engaged the attention of

men of science. It was only about the middle of the century that it began to be plainly seen that there existed such a science, and that the dynamic equivalence of heat, and energy in the mechanical form, was but a single fact, which must be taken in connection with the general principles of the persistence of energy, and applied in all cases of performance of work by expenditure of heat through the action of elastic bodies.

The Development of the Science of Thermodynamics into available and satisfactory form was effected mainly by Professors Rankine and Clausius, working independently but contemporaneously from 1849. Clausius developed the general theory with beautiful clearness and conciseness of mathematical method and work, and succeeded in constructing a complete system, almost equal in extent and exactness to the geometrical system of Euclid. Rankine, producing the same results, in part, by his wonderfully condensed method of treatment, turned his attention more closely to the application of the theory to the case of the steam and other heat engines, giving, finally, in his "Prime Movers" (1859), a concise yet full exposition of the correct theory of those motors, so far as it is possible to do so by purely thermodynamic treatment. He was unaware, apparently, as were all the scientific men of his time, of the extent to which the conclusions reached by such treatment of the case are modified, in real engines, by the interference of other physical principles than those taken cognizance of by his science. Sir Wm. Thompson, partly independently, and partly working with Joule, has added much valuable work to that done by Clausius and Rankine. In the hands of these great men the science took form, and has now assumed its place among the most important of all branches of physical science.

The Theory of the Steam Engine, like every other scientific system, rests upon a foundation of facts ascertained by experiment, and of principles determined by the careful study of the laws relating to those facts, and controlling phenomena, properly classed together by that science. Like every other element entering into the composition of a scientific system, this theory has been developed subsequently to the establishment of its fundamental facts, and the history of progress in the art to which it relates shows that the art has led the science from the first. The theory of the steam engine includes all the phenomena and all the principles involved in the production of power, by means of the steam engine, from the heat-energy derived from the chemical

combination of a combustible with the oxygen of the air acting as a supporter of the combustion. The complete theory therefore includes the theory of combustion; the consideration of the methods of development and transfer, and of losses of heat in the steam boiler; the examination of the methods of transfer of heat-energy from boiler to engine, and of waste of heat in this transfer, and, finally, the development of mechanical energy in the engine, and its application, beyond the engine, to the machinery of transmission, with an investigation of the nature and method of waste in this last transformation. It is, however, only the last of these divisions of the subject that it is here proposed to consider. The remaining portion of this paper will be devoted to the tracing of the growth of the theory of the steam engine, simply as a mechanical instrument for transformation of the one form of energy into the other,—of the molecular energy of heat motion, as stored in the vapor of water, into mass energy, mechanical energy, as applied to the driving of mechanism. The theory thus limited includes a study of the thermodynamic phenomena, as the principal and essential operations involved in the performance of work by the engine; it further includes the consideration of the other physical processes which attend this main function of the engine, and which, inevitably and unavoidably, so far as is to-day known, concur in the production of a waste of energy.

Of all the heat sent forward by the steam boiler to the engine, a certain part, definite in amount and easily calculated when the power developed is known, is expended by transformation into mechanical energy; another part, equally definite and easily calculated, also, is expended as the necessarily occurring waste which must take place in all such transformations, at usual temperatures of reception and rejection of heat; still another portion is lost by conduction and radiation to surrounding bodies; and, finally, a part, often very large in comparison with even the first and principal of these quantities, is wasted by transfer, within the engine, from the induction to the eduction side, "from steam to exhaust," by a singular and interesting process, without conversion into useful effect. The science of thermodynamics only takes cognizance of the first, which is sometimes one of the smallest of these expenditures. The science of the general physics of heat takes cognizance of the others.

The Science of the Phenomena of the Steam Engine must, like every other branch of applied science, be considered as the product of

two distinct processes of development; the one is what may be called the experimental development of the subject, the other is the purely theoretical progress of the science. So far as the useful application of principles to the perfection of the machine is concerned, the latter has always, as is usually the case elsewhere, been in advance of the former in its deduction of general principles; while, as invariably, the former has kept far in advance, in the working out of practically useful results, and in the determination of the exact facts where questions of economic importance have arisen. It is proposed here to follow the history of the experimental development of the principles controlling the efficiency of the engine, and modifying the conclusions derived by the application of the science of heat transformation, after first tracing the progress of the development of that science. The gradual formation of the pure theory of the steam engine will be traced, and the limitations of that theory will naturally come up for consideration afterward.

The germ of a Science of the Steam Engine may be found in the work of Sadi Carnot, published just sixty years ago. Although familiar with the then doubted mechanical theory of heat, he was not sufficiently well convinced of its correctness, apparently, to make it the basis of his work, but assumed, throughout his "*Reflexions sur la Puissance Motrice du Feu*," the theory of substantial caloric. Nevertheless, in his development of the theory of heat engines, he enunciated some essential principles, and thus laid the foundation for a theory of the steam engine which was given correct form, in all its details, as soon as the dynamical theory was taken for its foundation principle. Carnot asserts that "The motive power of heat is independent of the means taken to develop it; its amount is determined, simply, by the temperature of the bodies between which the heat is transferred. Wherever there exists a difference of temperature, there may be a development of power. The maximum amount of power obtainable by the use of steam is the maximum obtainable by any means whatever. High pressure engines derive their advantage over low pressure engines simply from their power of making useful a greater range of temperature." He made use of the device known as the "Carnot Cycle," exhibiting the successive expansions and compressions of the working fluid in heat engines, in the process of change of volume and temperature, while following the series of changes which gives the means of transformation of heat into power with final restoration of the fluid to its initial condition, showing that such a complete cycle must be tra-

versed in order to determine what proportion of the heat energy available can be utilized by conversion into mechanical energy. This is one of the most essential of all the principles comprehended in the modern science. This "Carnot Cycle" was, afterward, represented graphically by Clapeyron.

Carnot shows that the maximum possible efficiency of fluid is attained, in heat engines, by expanding the working fluid from the maximum attainable temperature and pressure down to the minimum temperature and pressure that can be permanently maintained on the side of condensation or rejection, *i. e.*, if we assume expansion according to the hyperbolic law, by adopting, as the ratio of expansion, the quotient of maximum pressure divided by back pressure. He further shows that the expansion, to give maximum efficiency, should be perfectly adiabatic. These principles have been recognized as correct by all authorities, from the time of Carnot to the present time, and have been, not infrequently, brought forward as new by minor later writers unfamiliar with the literature of the subject. Introducing into the work of Carnot the dynamical relation of heat and work, a relation, as shown by other writings, well understood, if not advocated publicly by him, the theory of the steam engine becomes well defined and substantially accurate. The Count de Pambour, writing in 1835, and later, takes up the problem of maximum efficiency of the steam engine, shows the distinction to be drawn between the efficiency of fluid and efficiency of machine, and determines the value of the ratio of expansion for maximum efficiency of engine. He makes this ratio equal to the quotient of maximum initial pressure divided by the sum of the useless internal resistances of the engine, including back pressure and friction, and reduced to equivalent pressure per unit of area of piston. This result has been generally accepted, although sometimes questioned, and has been demonstrated anew, in apparent ignorance of the fact of its prior publication by De Pambour, by more than one later writer. De Pambour, applying his methods to the locomotive, particularly, solved the problem, since distinctively known by his name: Given the quantity of steam furnished by the boiler in the unit of time, and the measure of resistance to the motion of the engine; to determine the speed attainable.

Professor Thomas Tate, writing his "Mechanical Philosophy," in 1853, gives the principle stated above a broader enunciation, thus: "The pressure of the steam, at the end of the stroke, is equal to the

sum of the resistances of the unloaded engine, whatever may be the law expressing the relation of volume and pressure of steam."

Professor Clausius, as has been already stated, applied the modern theory of the steam engine to the solution of the various problems which arise in the practice of the engineer, so far as they can be solved by the principles of thermodynamics. His papers on this subject were printed in 1856. The Count de Pambour had taken a purely mechanical mode of treatment, basing his calculations of the work done in the cylinder of the steam engine upon the hypothesis of Watt, that the weight of steam acting in the engine remained constant during expansion, and that the same assumption was applicable to the expanding mass contained in engine and boiler during the period of admission. He had constructed empirical formulas, published in his work on the theory of the steam engine, in 1844, for the relation of volume and pressure, during expansion, and had based his determinations of the quantity of work done, and of expenditure of steam in the engine, upon this set of assumptions and formulas, considering the steam to remain in its initial condition of dry and saturated vapor, or of moist vapor, as the case may be, from the beginning to the end of the stroke. Errors were thus introduced, which, although not important in comparison with those often occurring when the results of purely thermodynamic, and in so far correct, treatment was compared with the actual case, were, nevertheless, sufficiently great to become noticeable when the true theory of heat engines became known, and correctly applied. Clausius proved that, in the expansion of dry and saturated steam, doing work in the engine, condensation must take place to a certain extent, and that, consequently, the weight of steam in the cylinder must be somewhat reduced by the process of expansion beyond the point of "cut-off." During the period of compression, also, the reverse effect must occur, and the compressed mass must become superheated, if initially dry. He showed that the amount of work actually done in a non-conducting working cylinder must be sensibly different from that estimated by the method of De Pambour. Taking advantage of the redetermination of the constants in Regnault's equations effected by Moritz. Clausius obtains numerical results in the application of the true theory, and deduces the amount of work done in the steam engine under various conditions such as are met with in practice. He shows how the action of the engine may be made that of the Carnot Cycle, and determines the effect of variation of the temperature of the "prime"

steam. The investigation is, in the main, purely theoretical, no application is made to the cases met with in real work, and the comparison of the results of the application of the new theory to practice in steam engineering is left for others.

The work of Clausius is, throughout, perfectly logical, and beautifully simple and concise, and his application of the theory to the steam engine amounts to a complete reconstruction of the work of Carnot, and his followers, upon a correct basis. He developes with mathematical exactness of method and work the fundamental principles of the science of thermodynamics, constructs the "fundamental equations," the so-called "General Equations of Thermodynamics," and, in the course of his work, proves the fact of the partial condensation of saturated steam, when permitted to expand doing work against resistance.

Professor Rankine began his work upon the theory of the transformation of heat into mechanical energy at about the same time with Clausius (1849), and published his first important deduction, the form of the General Equation of Thermodynamics, nearly simultaneously, but a little earlier. He gave much attention to the then incomplete work of development of applied thermodynamics, and produced not only the whole theory of the science, but very extended papers, including solutions of practical problems in the application of the science to heat engines. Stating with singular brevity and clearness the main principles, and developing the general equations in substantially the same form, but by less easily followed processes, than his contemporary, he proceeded at once to their application. He determines the thermodynamic functions for air and other gases, exhibits the theory of the hot-air engine, as applied to the more important and typical forms, deduces expressions for their efficiency, and estimates the amount of heat demanded, and of fuel consumed, in their operation, assuming no other expenditure of heat than that required in an engine free from losses by conduction and radiation. He next, in a similar manner, applies the theory to the steam engine, proves the fact of the condensation of steam during the period of expansion, estimates the amount of heat, fuel, and steam expended, and the quantity of work done, and determines thus the efficiency of the engine. He makes a special case of the engine using superheated steam, as well as that of the "jacketted" engine, considers the superheated steam engine, and the binary vapor engine, and reconstructs De Pambour's problem. Applying the theory

of the steam engine to a considerable number of cases, differing in the steam pressure and in the ratio of expansion adopted, and including both condensing and non-condensing engines, he constructs a table exhibiting the efficiency of the steam, and the probable consumption of fuel (assuming a somewhat low efficiency of boiler) which table represents the limit of efficiency under the assumed conditions, a limit which may be approached as the conditions of practice approximate to those of the ideal cases taken, but which can never be reached.

As Rankine was not aware of the often enormous difference produced in the performance of the steam engine by the extra thermodynamic phenomena involved in its operation, he does not indicate the fact that the results of his calculations must be taken with the qualification just stated above, and his figures are still sometimes supposed to represent those of actual performance. The fact is, however, that the consumption of steam, and of fuel, in actual practice, always considerably exceeds those obtained by the solution of the thermodynamic problem, and, often, as already stated, exceeds that quantity by a very large amount.

Since the time of Rankine's and Clausius' investigations, the thermodynamic theory of the steam engine has received no important modifications, and the work of later engineers, and of physicists working upon the general subject, has been confined to the study, experimental or other, of the limitations set to the application of this theory by the influence of other physical phenomena.

Rankine's work included the construction of a remarkably exact, though hypothetical, equation expressing the relation of temperatures and pressures of vapors, based upon his theory of "molecular vortices," a comparison of the efficiencies of air and steam engines working between the same limits of temperature, and an exceedingly beautiful method of graphically determining the most economical size of steam engine, from the commercial point of view, the quantity of power required being given, and all expenses being calculable. He defined and outlined the science of "energetics," established the beginnings of a system of graphical thermodynamics, including the representation of the action of steam in the compound engine. He studied the action of explosive gas engines, and calculated the explosive energy of liquids heated under pressure. Besides all this, Rankine performed an enormous amount of work in mathematical physics, in hydrodynamics, in hydromechanics, in the theory of naval architecture, and

in the application of mechanics to general engineering. Several important text-books, a large volume on shipbuilding, and other works, with an unknown number of papers, published and unpublished, form a monument to the power and industry of this wonderful man and remarkable genius, that may be looked upon as perhaps the greatest wonder of the intellectual world.

The Thermodynamic Theory of the Steam Engine stands, to-day, substantially as it was left by Clausius and Rankine at the close of their work in this field, in the decade 1850 to 1860. Many treatises have been published, some of them by men of exceptional ability; but all have followed the general line first drawn by these masters, and have only now and then found some minor point to develop. Rankine's "Steam Engine and other Prime Movers," written a quarter of a century ago, is still a standard work on the theory of the heat engines, and is still used as a text-book in engineering schools in this country and Europe.

The Limitations of the Thermodynamic Theory of the Heat Engines, and of its application in the design and operation of such engines were first discovered by James Watt, a hundred years ago and more. They were systematically and experimentally investigated by Isherwood, in 1855 to 1865, were observed and correctly interpreted by Clark, in 1855 and earlier, and were revealed again by the experiments of Hirn, and by those of Emery and many other recent investigators on both sides of the Atlantic. These limitations are due to the fact that losses occur in the operation of steam engines which are not taken into account by the hitherto accepted theory of the engine, and have no place in the thermodynamic treatment of the case.

It is usually assumed, in the usual theory of the engine, that the expansion of the working fluid takes place in a cylinder having walls impermeable to heat, and in which no losses by conduction or radiation, or by leakage, can occur. Of those losses which actually take place in the real engine, that due to leakage may be prevented, or, if occurring, can be checked; but it is impossible, so far as is now known, to secure a working cylinder of perfectly non-conducting material. The consequence is that, since the steam or other working fluid enters at a high temperature and is discharged at a comparatively low temperature, the surfaces of cylinder, cylinder heads and piston, are, at one instant, charged with heat of high temperature, and at the next moment, exposed to lower temperatures, are drained of their surplus

heat, which heat is then rejected from the cylinder and wasted. Thus, at each stroke, the metal surfaces, exposed to the action of the expanding substance, alternately absorb heat from it, and surrender that heat to the "exhaust." In the case of the gas engines, this waste is rendered enormously greater by the action of the water-jacket, which is there needed to keep the cylinder down to a safe temperature, and which takes away, in the circulating stream of cooling water, an immense amount—usually about one half—of the heat received from the burning gas. In the steam engine, the loss by the method here referred to is rarely less than one-fourth, in unjacketted cylinders, and is often more than equal to the whole quantity of heat transformed into mechanical energy. The amount of this loss increases with wet steam and is diminished by any expedient, as steam-jacketting or superheating, which prevents the introduction or the production of moisture in the midst of the mass of steam in the cylinder. As the range of temperature worked through in the engine increases, as the quantity of steam worked per stroke diminishes, and as the time allowed for transfer of heat to and from the sides and ends of the cylinder and the piston is increased, the magnitude of this loss increases. Hence the use of high steam, of a high ratio of expansion, and of low piston speed, tends to increase the amount of this waste, while low steam, a low ratio of expansion and high engine speed, tend to diminish it. These physical phenomena are therefore no less important in their influence upon the behavior of the engine, and upon its efficiency, and are no less essential elements for consideration in the general theory of the engine than those taken into account in the purely thermodynamic theory.

James Watt, as above stated, discovered this cause of the limitation of the efficiency of the steam engine. He not only discovered the fact of the existence of this method of waste, but experimentally determined its amount in the first engine ever placed in his hands. It was in 1763 that he was called upon to repair the little model of the Newcomen engine, then and still in the cabinets of the University of Glasgow. Making a new boiler, he set up the machine and began his experiments. He found, to his surprise, that the little steam cylinder demanded four times its own volume, at every stroke, thus wasting, as he says, three-fourths of the steam supplied, and requiring four times as much "injection-water" as should suffice to condense a cylinder full of steam. It was in the course of this investigation that he discovered

the existence of so-called "latent heat." All of Watt's first inventions were directed toward the reduction of this immense waste. He proposed to himself the problem of keeping the cylinder "as hot as the steam that entered it;" he solved this problem by the invention of the separate condenser and the steam jacket, and thus the discovery of the limitation of the thermodynamic theory here noted was the source of Watt's fame and fortune.

John Smeaton, a distinguished contemporary of Watt, and perhaps the most distinguished engineer of his time, seems to have been not only well aware of this defect of the steam engine, but was possibly even in advance of Watt in attempting to remedy it. He built a large number of Newcomen engines between 1765 and 1770, in some, if not many of which, he attempted to check loss of this now familiar "cylinder condensation" in engines, some of which were five and six feet in diameter of cylinder, by lining pistons and heads with wood. This practice may not be practicable with the temperatures now usual; but no attempt has been made, so far as is known to the writer, to follow Smeaton in his thoroughly philosophical plan of improvement. Cylinder-condensation remains to-day, as in the time of Smeaton and Watt, the chief source of waste in all well designed and well constructed heat engines.

It is a curious fact, and one of great interest as illustrating the gulf formerly separating the philosopher, studying the steam engine and working out its theory, from the practitioner engaged in its construction and operation, in the earlier days of engineering, that, notwithstanding the fact that this waste was familiar to all intelligent engineers, from the time of the invention of the modern steam engine, and was recorded in all treatises on engine construction and management, the writers on the theory of the machine have apparently never been aware that it gives rise to the production, in the working cylinder, of a large amount of water mingled with the steam. In fact it has often been assumed by engineers themselves, that this water is always due to "priming" at the boiler. Even Rankine, writing in 1849–'50, while correctly describing the phenomenon of cylinder-condensation, made the mistake of attributing the presence of the water in steam cylinders to the fact of condensation of dry steam doing work by expansion, apparently not having noted the fact that this would only account for a very insignificant proportion of the moisture actually present in the average

steam engine. He considers incomplete expansion the principal source of loss, as do usually other writers on thermodynamics.

Thomas Tredgold, writing in 1827, who, but little later than Carnot, puts the limit to economical expansion at the point subsequently indicated and more fully demonstrated by De Pambour, exaggerates the losses due to the practical conditions, but evidently does perceive their nature and general effect. He also shows that under the conditions assumed, the losses may be reduced to a minimum, so far as being dependent upon the form of the cylinder, by making the stroke twice the diameter.

The limit of efficiency in heat engines, as has been seen, is thermodynamically determined by the limit of complete expansion. So well is this understood, and so generally is this assumed to represent the practical limit, by writers unfamiliar with the operation of the steam engine, that every treatise on the subject is largely devoted to the examination of the amount of the loss due to what is always known as "incomplete expansion"—expansion terminating at a pressure higher than the back pressure in the cylinder. The causes of the practical limitation of the ratio of expansion to a very much lower value than those which maximum efficiency of fluid would seem to demand, have not been usually considered, either with care or with intelligence, by writers thoroughly familiar with the dynamical treatment, apart from the modifying conditions here under consideration.

Watt, and probably his contemporaries and successors, for many years supposed that the irregularity of motion due to the variable pressure occurring with high expansion was the limiting condition, and does not at first seem to have realized that the cylinder-condensation discovered by him had any economical bearing upon the ratio of expansion at maximum efficiency. It undoubtedly is the fact that this irregularity was the first limiting condition with the large, cumbrous, long-stroked, and slow-moving engines of his time. Every accepted authority from that day to the present, has assumed, tacitly, that this method of waste has no influence upon the value of that ratio, if we except one or two writers who were practitioners rather than scientific authorities.

Mr. D. K. Clark, publishing his "Railway Machinery," in 1855, was the first to discuss this subject with knowledge, and with a clear understanding of the effects of condensation in the cylinder of the steam engine, upon its maximum efficiency. Cornish engines, from

the beginning, had been restricted in their ratio of expansion to about one-fourth, as a maximum, Watt himself adopting a "cut-off" at from one-half to two-thirds. Hornblower, with his compound engine competing with the single cylinder engines of Watt, had struck upon this rock, and had been beaten in economy by the latter, although using much greater ratios of expansion; but Clark, a half century and more later, was, nevertheless, the first to perceive precisely where the obstacle lay, and to state explicitly that the fact that increasing expansion leads to increasing losses by cylinder condensation, the losses increasing in a much higher ratio than the gain, is the practical obstruction in our progress toward greater economy.

Clark, after a long and arduous series of trials of locomotive engines, and prolonged experiment looking to the measurement of the magnitude of the waste produced as above described, concludes: "The magnitude of the loss is so great as to defeat all such attempts at economy of fuel and steam by expansive working, and it affords a sufficient explanation of the fact, in engineering practice, that expansive working has been found to be expensive working, and that, in many cases, an absolutely greater quantity of fuel has been consumed in extended expansion working, while less power has been developed." He states that high speed reduces the effect of this cause of loss, and indicates other methods of checking it. He states that "the less the period of admission, relative to the whole stroke, the greater the quantity of free water existing in the cylinder." His experiments, revealing these facts were, in some cases, made prior to 1852. But the men handling the engines had observed this effect even before Clark; he states that they rarely voluntarily adopted "a suppression of above 30 per cent.," as they found the loss by condensation greater than the gain by expansion. Describing the method of this loss, this author goes on to say that "to prevent entirely the condensation of steam worked expansively, the cylinder must not only be simply protected by the non-conductor; it must be maintained, by independent external means, at the initial temperature of the steam." He thus reiterates the principle expressed by Watt, three-quarters of a century before, and applies it to the newly stated case.

The same author, writing in 1877, says: "The only obstacle to the working of steam advantageously to a high degree of expansion in one cylinder, in general practice, is the condensation to which it is subjected, when it is admitted into the cylinder at the beginning of the

stroke, by the less hot surfaces of the cylinder and piston; the proportion of which is increased so that the economy of steam by expansive working ceases to increase when the period of admission is reduced down to a certain fraction of the stroke, and that, on the contrary, the efficiency of the steam is diminished as the period of admission is reduced below that fraction." The magnitude of this influence may be understood from the fact that the distinguished engineer, Loftus Perkins, using steam of 300 pounds pressure, and attaining the highest economy known, up to his time, found his engine to consume 1·62 pounds of fuel per hour and per horse-power; while this figure is now reached by engines using steam at one-third that pressure, and expanding about the same amount, and sometimes less.

Mr. Humphreys, writing a little later than Clark, shows the consumption of fuel to increase seriously as the ratio of expansion is increased beyond the very low figure which constituted the limit in marine engines of his time.

Mr. B. F. Isherwood, a Chief Engineer in the United States Navy, and later Chief of the Bureau of Steam Engineering, seems to have been the first to have attempted to determine, by systematic experiment, the law of variation of the amount of cylinder-condensation with variation of the ratio of expansion, in unjacketed cylinders. Experimenting on board the U. S. S. *Michigan*, he found that the consumption of fuel and of steam was greater when the expansion was carried beyond about one-half stroke than when restricted to lower ratios. He determined the quantity of steam used, and the amount condensed, at expansions ranging from full stroke to a cut-off at one-tenth. His results permit the determination of the method of variation, with practically satisfactory accuracy, for the engine upon which the investigation was made, and for others of its class. It was the first of a number of such investigations made by the same hand, and these to-day constitute the principal part of our data in this direction. The writer, studying these results, found that the cylinder condensation varied sensibly as the square root of the ratio of expansion, and this is apparently true for other forms and proportions of engine. The amount of such condensation usually lies between one-tenth and one-fifth the square root of that ratio, if estimated as a fraction of the quantity of steam demanded by a similar engine having a non-conducting cylinder.

The state of the prevalent opinion on this subject, at the time of this

work of Clark and of Isherwood, is well expressed by the distinguished German engineer, Dr. Albans, who, writing about 1840, says of the choice of best ratio of expansion: "Practical considerations form the best guide, and these are often left entirely out of view by mathematicians. Many theoretical calculations have been made to determine the point, but they appear contradictory and unsatisfactory." Renwick, in 1848, makes the ratio of initial divided by back pressure the proper ratio of expansion, but correctly describes the effect of the steam jacket, and suggests that it may have peculiar value in expansive working, and that the steam may receive heat from a cylinder thus kept at the temperature of the "prime" steam. John Bourne, the earliest of now acknowledged authorities on the management and construction of the steam engine, pointed out, at a very early date, the fact of a restricted economic expansion. Rankine recognized no such restriction as is here under consideration, considered the ratio of expansion at maximum efficiency to be the same as that stated by Carnot, and by other early writers, and only perceived its limitation by commercial considerations, a method of limitation of great importance, but often of less practical effect than is the waste by condensation. In his life of Elder (1871), however, he indicates the existence of a limit in practice, and places the figure at that previously given by Isherwood, for unjacketted engines. By this latter date, the subject had become so familiar to engineers that a writer in "London Engineering," in 1874, contemns writers who had neglected to observe this limitation of efficiency as indulging in "mediæval twaddle."

A few writers on thermodynamics finally came to understand the fact that such a limitation of applied theory existed. Mons. G. A. Hirn, who, better than probably any authority of his time or earlier, combined a knowledge of the scientific principles involved, with practical experience and experimental knowledge, in his treatise on thermodynamics (1876), concludes: "*qu'il est absolument impossible d'édifier* a priori *une théorie de la machine á vapeur d' eau douce d'un charactere scientifique et exact*," in consequence of the operation of the causes here detailed. While working up his experiments upon the performance of engines, comparing the volume of steam used with that of the cylinder, he had always found a great excess, and had, at first, attributed it to the leakage of steam past the piston; but a suggestion of M. Leloutre set him upon the right track, and he came to the same conclusion as had Watt, so many years before. He explains that errors of thirty, or even

up to seventy, per cent., may arise from the neglect of the consideration of this loss. Combes had perceived the importance of this matter, and De Freminville suggested the now familiar expedient of compression, on the return stroke, as nearly as possible to boiler pressure, as a good way to correct the evil. The matter is now well understood by contemporary writers, and it has become fully agreed, among theoretical writers as well as among practitioners, that the benefit of extended expansion in real engines can only be approximated to that predicted, by the theory of the ideal engine, by special arrangements having for their object the reduction of cylinder waste, such as superheating, "steam jacketing" and "compounding."

Professor Cotterill has given more attention to this subject than any writer up to the present time. He devotes a considerable amount of space to the study of the method of absorption and surrender of heat by the metal surfaces enclosing the steam, constructs diagrams which beautifully illustrate this action, and solves the problems studied by him with equal precision and elegance of method. He summarizes the experimental work done to the date of writing, and very fully and clearly exhibits the mode of transfer of heat past the piston without transformation into work. Professor Cotterill's treatise on the steam, "considered as a heat engine," is invaluable to the engineer.

Thus the theory of the steam engine stands to-day, incomplete, but on the verge of completion, needing only a little well directed experimental work to supply the doubtful elements. Even these are becoming determined. Isherwood gives facts showing waste to be proportional, very nearly, if not exactly, to the square root of the ratio of expansion, and Escher, of Zurich, has shown the loss to be also proportional to the square root of the time of exposure, or, in other words, to the reciprocal of the square root of the speed of rotation, and it only remains to determine the method of variation of loss with variation of range of temperature to give the whole of the necessary material for the construction of a working theory which will enable the engineer to estimate, in advance of construction, the economic performance of his machine. There will, undoubtedly be much more to be done in constructing an exact theory involving all the physical changes occurring in the working of the heat engines familiar to us; but it will yet be done, and probably very soon. It is the hope of the writer that experiments made under his direction, recently, may furnish the needed data, as the result of the first systematic research directed

to that end; but if this should prove not to be the fact, it cannot be long before direct investigation will secure all essential knowledge. When this is the case the remarks of those distinguished physicists and engineers, Hallauer, and his great teacher, Hirn, will be no longer well based upon apparent fact.

Says Hirn, in his memorable discussion with Zeuner, in regard to this subject, "*Ma conviction reste aujourd'hui qu'elle etait il y a vingt ans, une théorie proprement dite de la machine à vapeur est impossible; la théorie experimentale, etablie sur le moteur luimeme et dans toutes les formes ou il a été essayé, en mecanique appliqué peut seule conduire a des resultats rigoureux.*"

At present, it seems only possible, in the absence of a complete experimental examination, to do more than to base the determination of the ratio of maximum efficiency upon such experience as is familar to engineers. Mr. C. E. Emery considers that, for common unjacketed engines, it is practically safe to take the ratio for maximum duty at a figure expressed by an empirical formula proposed by him: $r = (p + 37) \div 22$. The writer has usually taken it, in estimates, as not far from one-half the square root of the boiler pressure expressed, as before, in pounds on the square inch. These points of cut-off are reduced still further by the fact that, commercially, it is better to reduce the size of engine at the expense of efficiency, as the cost of fuel and of similarly variable expenses increase. This is however, a matter for the treatment of which space cannot here be taken. Rankine has devised a convenient method of solving such problems, involving this condition, as may arise in practice, where cylinder-condensation may be neglected, and the writer has found a method of adapting it to ordinary practice. The subject will ultimately form, properly, a final division of the complete theory of the steam engine.

Chronologically considered it is seen that the history of the growth of the theory of the steam engine divides itself distinctly into three periods, the first extending up to the middle of the present century, and mainly distinguished by the attempts of Carnot and of Clapeyron to formulate a physical theory of the thermodynamics of the machine, the second beginning with the date of the work of Rankine and Clausius, who constructed a correct thermodynamic theory, and the third beginning a generation later, and marked by the introduction, into the general theory, of the physics of the conduction and transfer of that heat which plays no part in the useful transformation of energy. The first period

may be said to include, also, the inauguration of experimental investigation, and the discovery of the nature and extent of avoidable wastes and attempts at their amelioration by James Watt and by John Smeaton. The second period is marked by the attempt, on the part of a number of engineers, to determine the method and magnitude of these wastes by more thorough and systematic investigation, and the exact enunciation of the law governing the necessary rejection of heat, as revealed by the science of thermodynamics. The third period is opening with promise of a complete and practically applicable investigation of all the methods of loss of energy in the engine, and of the determination, by both theoretical and experimental research, of all the data needed for the construction of a working theory.

Mons. Hirn has recognized these three periods, and has proposed to call the second "theoretical" and the third the "experimental" stage. The writer would prefer to make the nomenclature somewhat more accordant with what has seemed to him to be the true method of development of the subject. It has been seen that the experimental stage really began with the investigations of Watt in the first period, and that the work of experimentation was continued through the second into the present, the last period.

It is also evident that the theoretical stage, if it can be properly said that such a period may be marked off in the history of the theory of the steam engine, actually extends into the present epoch; since the work of the engineer and the physicist of to-day consists in the application of the science of heat-transfer and heat-transformation, together, to the engine. During the second period the theory included only the thermodynamics of the engine; while the third period is about to incorporate the theory of conduction and radiation into the general theory with the already established theory of heat-transformation. The writer would therefore make the classification of these successive stages in the progress here described thus:

1. Primary Period.—That of incomplete investigation and of earliest systematic, but inaccurate theory.

2. Secondary Period.—That of the establishment of a correct thermodynamic theory, the *Theory of the Ideal Engine.*

3. Tertiary Period.—That of the production of the complete theory of the engine, of the *true Theory of the Real Engine.*

The work of developing this theory is still incomplete. It remains to be determined, by experiment, precisely what are the laws of transfer

of heat between metal and vapor, in the engine cylinder, and to apply these laws in the theory of the machine. Cotterill has shown how heat penetrates and traverses the metal and Grashof has indicated the existence of an intermediate and approximately constant, temperature, between the temperatures of the initial steam and of the exhaust, and both have given us some new methods. The writer, while pointing out the nature of the true "curve of efficiency" of the steam engine which he was so fortunate as to discover, has shown how it may be made useful in the solution of practical and of theoretical problems involved in the applied theory of heat engines and many able minds are now engaged upon the theory. There can be little doubt that it will soon become satisfactorily complete.

HOBOKEN, N. J., July, 1884.

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CHANGES OF REFRANGIBILITY IN ELECTRIC SPECTRA.—It is well known that the hydrogen lines, in the spectra of solar spots and protuberances, are often suddenly displaced, so as to appear wavy or broken. This is especially the case with the C line. The velocities impressed upon the gaseous particles must be so enormous that there seemed little likelihood of reproducing the phenomena in the labratory. Cazin supposed that electricity might have sufficient velocity, but he felt the need of new investigations in that direction. Liveing and Dewar found that when a few drops of water were injected into the voltaic arc, there was a sudden enlargement of the hydrogen lines, quite comparable to that which is often observed in the solar atmosphere and attributed to eruptions. Fievey found similar phenomena, by passing a series of electric sparks between electrodes of magnesium which were only one or two millimetres apart, in a tube of three centimetres diameter, which was filled with hydrogen under a mercurial pressure of two metres. He employed a Christie spectroscope which gave, with a half prism, a dispersion equivalent to that of six flint prisms. The spark was furnished by a large coil, connected with a condenser and driven by a battery of ten bi-chromate of potassium elements. The electrodes were perpendicular to the slit, which was so regulated as to give the sodium lines with sharp definition. An objective was interposed between the electrodes and the slit. Under these circumstances the C hydrogen line and the magnesium lines b_1, b_2 and b_3 undulated, expanded and broke on the right and on the left.—*Bull. de l'Acad. Belg.* 1884. C.

SUNSETS IN CHINA.—Dechevrens, the director of the Observatory at Zi-kæ-wei, reports that the brilliant twilights and the green sun were observed in China, as well as in Europe, during the last autumn. On the other hand, during the winter, the zodiacal light appeared to him fainter than on preceding years. This corresponds with the testimony of Thollon and Perrotin at Nice, and of Janssen, at Meudon.—*Les Mondes*, April 18, 1884. C.

OUR CLOTHING AND OUR HOUSES.

By Louis W. Atlee, M. D.

All the English writers on the subject of Hygiene, including even Parkes and Wilson, whose systematic treatises are excellent in many respects, are signally deficient on the subjects of clothing and of houses. Of the truth of this any one can satisfy himself very speedily by trying to collect information about them; he will be forced to consult writers in other languages for what he wishes to know.

Necessary to our health and comfort as a knowledge of clothing and dwellings must be, it may be said, without exaggeration that more attention is devoted in our medical publications to new pharmaceutical preparations, and to ingenious pathological and etiological theories than to what is of such every-day practical intent.

In ordinary works on Hygiene the subject of sewerage is surely sufficiently well discussed and this may be true, also, for water supply. On the subject of clothing and of houses what is about to be said is almost entirely new to the English language. It is mainly in French writings and above all in an article in "La Révue des deux Mondes," for July 15, 1883, that the following ideas were found.

Our clothes and houses are the armor we use to protect us in our incessant fight with the elements. They are not destined to isolate us from the surrounding air, but to regulate our incessant and indispensable relations with it. These relations cannot be clearly understood without a knowledge of how the body is maintained at so equable a temperature under the most diverse influences. We know that the animal heat is produced by the chemical metamorphoses that take place in the tissues and principally, but not exclusively, by the combustion of the assimilated food carried into the circulation, which the oxygen respired, changes into carbonic acid and water. These combustions elevate the temperature of the blood, and the warm liquid that penetrates everywhere, heats the organism almost in the same way that a water-furnace heats a house. The activity of the respiration and the consumption of oxygen decreases during sleep; it is increased on the contrary during exercise, a part of the heat being converted into mechanical work. We may admit that a man who takes but little exercise, respires in the 24 hours, 10 c. m. of air, and absorbs about a quarter of the oxygen contained in it, say 650 grams of oxygen. The heat liberated by

these chemical actions may reach at a medium about 2,000 or 3,000 heat units; it would be sufficient to bring 20 or 30 litres of water to the boiling point, or to make the temperature of the body go up 3 degrees every hour. That the temperature of the body be constant is an indispensable condition to the health of the warm blooded animals.

What are the means by which nature arranges to supply any insufficiency of the interior heat, to eliminate any harmful excess, and to bring back the temperature of the organs to a degree that suits the accomplishment of the regular phenomena of life? These means are various. When the nutrition becomes insufficient, calorification is produced at the expense of the tissue of the animal, that we then see becomes thin; the herbivorous becomes temporarily carnivorous. When heat is produced in excess, the organism gets rid of it by a number of issues; in fact, the body is cooled by radiation, by evaporation and by conduction or contact. It is admitted that in ordinary weather one-half is carried off by radiation, the two other means taking each a quarter of the surplus heat.

Evaporation is the safety-valve that regulates the loss of heat in completing to a certain point the action of conduction and radiation. Thus, a large part of the caloric produced in excess is carried off by radiation. The intensity of this radiation by which the heat of our bodies is dispersed around, is proportionate to the difference that exists between the proper temperature of the body and that of the surrounding medium; it is augmented near an object that is very cold. For example, we explain thus the sensation of cold that persists, after a fire has been lighted in a room that has not been heated for a long time, notwithstanding that the temperature in the room may have reached 20°C., whilst it will be comfortable with the thermometer at 17° after a continued warming. It is because in the first case, that the walls and the furniture are still cold and abstract much heat in provoking radiation from our body. The loss becomes less, and the sensation of cold passes off, when the surrounding objects have reached a temperature in the neighborhood of 15°C. We can thus understand how dangerous it would be in winter to remain long seated near a wall or a window, that would cool only one side of the body by excessive radiation.

It is for a reason analogous to the above, that we feel too warm in a hall filled with people, when the temperature does not mount higher than 20°C. Because, the presence of a large number of people, all

having a temperature of 37°, impedes the lateral radiation, the excess of heat is only carried off by the currents of air and by a more copious perspiration. We then fan ourselves to increase the coolness by convection and by evaporation; by bringing a greater quantity of air in contact with the skin. If we leave the hall and go to "take a breath" in another room that has remained empty, we are astonished to see that the thermometer is nearly the same as in the hall; we feel cooler because the body radiates more freely.

The human body is cooled by convection in heating the air that surrounds it, and the loss will be perceptible in proportion to the temperature of the air and to the rapidity of its renewal.

The atmosphere, no matter how calm it may appear, is always agitated by a thousand different movements that are not perceptible to our senses, because, unless a current of air moves at least one metre a second, it makes no impression on our senses; a movement of 0·5 m. will not be felt; we can prove it by agitating gently our hand. An indirect proof of the existence of these currents, is the rapidity with which perfumes spread around in a calm atmosphere.

In our climate the medium rapidity of the currents of air that plough the free atmosphere is estimated at about 3 m. a second, or about eleven kilometers an hour. In admitting that the surface of the body exposed to the current of air is equal to 1 m. square, there passes over a man promenading outside, 11,000 cubic m. of fresh air in an hour.

It is astonishing how little civilization has done to aid us to combat heat when the most various and efficacious means have been invented to preserve us against cold. The Hindoo reduces the production of interior heat by taking little nourishment; but he has no energy and his capacity for work is very small. Assiduous work demands a larger amount of food, and from it results an amount of heat that is harmful, for the organism can only convert into mechanical work 25 per cent. of the increase of heat, that it produces during a sustained effort. It is not, therefore, the production of less heat we should try to effect, but how to relieve ourselves of that which is produced.

As a refrigerant, water is much more effective than air, because of its greater conductibility—at an equal temperature a bath of water will cool us much more than one of air, but the usage of baths is necessarily limited. The question of real importance is how to cool the air that comes in contact with our bodies.

We have yet to consider the pulmonary and cutaneous evaporation. In the tropics when the thermometer is higher than 37°F. in the shade, the body can no longer cool itself by contact or by radiation; there then only remains one way for the surplus heat to be carried off; it must be expended in vaporizing the water that is brought to the pulmonary mucus membrane and to the skin by transpiration.

As a general rule, half as much water is exhaled from the lungs as is excreted by the skin; in repose, the body loses by these two ways 900 grams of water that transforms itself into vapor, but this quantity can be doubled or tripled under the influence of on excess of interior heat, as the transpiration will then open its flood gates. Thus the vaporization of a kilogram of water at 37°C. absorbs 580 heat units; by transpiration at least 500 units are carried off in the 24 hours, that is to say, an amount of heat sufficient to make 5 litres of water boil. The vapor that is thus disengaged diffuses itself in the surrounding air, and the further the air is from its point of saturation the greater will be the facility with which the vapor is absorbed.

Indeed, for a given temperature there exists always a limit to the proportion of vapor that the air can contain; when it has reached this point, it is called saturated. At 37° a cubic metre of air contains 44 grams of water in a state of vapor, at 30° it can contain 30 grams, and at zero 5 grams only. From this we see that a cubic metre of dry air heated in our lungs to 37°C., can carry off 44 grams of vapor of water. But suppose that the air we are breathing is at zero and saturated with humidity, (5 grams to the cubic meter). When heated by respiration to 37°C., it can yet contain 39 grams; the difference will not be perceptible, but if the air is at a temperature of 30°C. and saturated (containing 30 grams of vapor of water to the cubic metre of air), it can only absorb 14 grams in place of 44 when the temperature will be raised to 37°F., we shall only lose 8 units in place of 25, and for 10 centimetres of air that we breathe in the 24 hours there will only be 80 instead of 250 units, making a difference of 170 units.

A hot and damp atmosphere feels so close, because it impedes the evaporation of the water brought by transportation to the surface of the body. Even the wind loses its power of drying. This is why a damp and hot climate is so much more unhealthy than a dry and hot one.

The lightest veil is something of a vestment, as it serves to moderate the loss by radiation from a naked body. It is in the same way that

a cloudy sky in the spring protects the earth from being too much cooled, the dew will only fall when the clouds are absent. In putting on numerous coverings, whose thickness we increase according to the rigor of the seasons, we succeed in diminishing the radiation from our bodies, as if by a series of stopping off places or relays.

Our linen, underclothes, and our cloaks, make up numerous artificial epiderms. The heat that is given off by the skin goes to warm the superimposed covering; the worse the conductor, the slower the heat will pass through; when it arrives at the surface it goes off, but without our perceiving it, as in direct contact of the air we should, since it is not we but the clothes that get cold. What renders our clothes a protection to us is their being wadded with a layer of warm air, the temperature of which is maintained at between 20° and 30°C. Each of us thus has his own little atmosphere that follows him everywhere and renews itself without getting cold. An animal, in its fur, has its couch of air in the interstices, that increases the protecting power. Furs, soft stuffs and feathers owe their warmth to the air that they contain.

It is evidently a question of great interest to determine by experiments the facility with which the various stuffs used as clothing are traversed by heat. The celebrated Count de Rumford was the first who particularly studied these experiments. He used a glass ball with a diameter of 0·04 m., surmounted by a tube through which he introduced into the ball a thermometer surrounded by the substance to be examined. The ball was first put in boiling water, and then into a cooling mixture, and he noted the time that it took the thermometer to descend from 70°R. to 10°R., or to loose 60° Réaumur (75°C.) When the thermometer was bare it cooled in 9·5 minutes. Where it was covered with linen it took 13 minutes. Covered with other kinds of stuffs it took periods of time longer and longer to cool; flax or cotton thread, 14 or 15 minutes; silk or woolen thread, 15 or 16 minutes; flax lint, cotton wadding, 17 minutes; sheep's wool, 18½ minutes; raw silk, 21 minutes; eider down, hare's fur, 22 minutes. These experiments were made in 1798.

The most recent experiments were made by Dr. Krieger. He used a sheet-iron cylinder filled with hot water, which he covered with different stuffs, noting their effect in impeding the cooling of the water. In investing the cylinder successively with a covering of wool, buckskin, silk, cotton, flax (always taking note of the temperature), he only found an insignificant difference, not exceeding 1 or 2 in 100. The

color made no difference. From this it seems that, as long as we use obscure heat, the emissive power, and the absorbing power, which is correlative of it, varies very little in the different stuffs. It is very different if we use luminous heat, or solar rays. With coverings of flax, cotton, flannel, silk, M. Krieger noted the absorption of heat in the proportions as shown by the following numbers: 90, 100, 102, 108. The influence of color was much greater; for cotton stuffs, differently tinted, he found the following numbers:

White	100	Dark green	168
Straw-color	102	Turkish red	165
Yellow	140	Light blue	198
Light green	155	Black	208

To have an idea of the part played by the conductibility of tissue, M. Krieger ascertained in what measure the loss of caloric was diminished by doubling the various stuffs placed around the iron cylinder. He found that satin, cotton stuffs and fine linen, only diminished the loss from 3 to six per cent.; for buckskin, flannel and rather thick cloth, the loss was lessened from 10 to 20 or even 30 per cent.

The clearest result of these experiments is that the resistance offered by these various stuffs does not depend so much on the conductibility of the textile fibres that form their substance, as on their thickness, volume and texture.

A coat that is wadded is much warmer when new, than it is after the wadding has been flattened by its use, as it is thus rendered a better conductor. If the doubling of the covering of the cylinder has little influence when they are wrapped tightly around, it is very different when a space of $\frac{1}{2}$ or 1 centimetre has been left between the two layers. We find, in deducing for the conductibility of the two layers, a retardation of the cooling amounting to 30 or 35 per cent., that is caused by the interposed layer of air, as it is independent of the nature of the covering. From this it follows, that in certain cases, a garment will keep us warmer if it is large, than if it was tight; we know that tight gloves or shoes protect us badly against the cold. But in this reasoning we suppose that the layer of air is immovable; a large, flowing garment is really cooler, being favorable to the circulation of the air. The most serious obstacle that the propagation of heat can encounter in a body, is the discontinuity of its elements. In the manufacture of the various tissues destined to clothe us, these principles are profited by, more or less unknowingly. Very warm clothes are obtained from

stuffs that are light, spongy and loose, because they can contain a large volume of air in the interstices between the fibres; I said contain, but it would be more correct to have said, allow to pass. Indeed, the warm air that surrounds our bodies is not immovable, it is renewed by filtering through the coverings that we think are destined to isolate us from the surrounding medium. A condition that is essential for a good garment is, that it allows of ventilation. The warmest stuffs allow the air to pass through them more freely than those that are considered the coolest. M. Pettenkoffer has demonstrated the proof of this, in measuring the volumes of air that passed through a series of tubes, closed with different kinds of stuffs, the same pressure and time being allowed for each kind of stuff; the following numbers will give an idea of their relative permeability:

Flannel	100	Heavy cloth	58
Linen	58	Buckskin	51
Silk	40	Glazed skin	1

Flannel is one hundred times more permeable than a glazed glove, yet we know that it is infinitely warmer. In using double layers the volumes of air were only slightly modified. Thus we see that our clothes are continually aired, and the activity of the exchange depends on the exterior temperature, the agitation of the atmosphere, and on the porosity of the tissues; what is essential is, that the exchange should be made so slowly as to be imperceptible.

The warmest garment is a fur pelisse; but it is not only the skin, it is above all the hair that keeps the heat, even if its mass should be comparatively insignificant; the heating efficacy of this kind of apparel is due, above all, to the interposed air. M. Krieger has an interesting experiment on this subject; he noted the loss of heat by his calorimetre first, when surrounded with fur in its natural state, then with the skin shaved, and lastly, the same skin was coated with a varnish of linseed oil, then with one of gum-arabic; the loss in these four cases is shown in the following figures: 100, 190, 258, 296. The cleansed skin lost twice as much heat as when it had the hair on, and the loss was tripled by the varnish that closed the pores.

Dogs and rabbits have been killed by being shaved and then varnished; death being caused, not so much by the suppressed respiration as by the loss of heat.

M. Krieger found that when he shaved a rabbit and wrapped it in wet linen and left it in a room at a temperature of 19°C.; the tempera-

ture of the animal fell in five hours from 39·8°C. to 24·5°; in the same time the frequency of the respiration fell from 100 to 50 inspirations a minute. On putting the rabbit in a cage heated to 30°, it was quickly revived.

Air-tight garments are in general unhealthy, being an obstacle to the aeration of the clothes underneath. They are useful to protect us from the rain, but they excite perspiration and prevent it from vaporizing.

An important quality of stuffs is their hygroscopicity. All tissues are hygroscopic; they condense the atmospheric humidity, and the more the atmosphere is saturated the quicker they absorb the moisture, the air being the less capable of vaporizing it. This condensation takes place particularly when the temperature is lowered. When water is absorbed by any cloth, it is divided into two parts, one that can neither be felt or expressed, which is the true hygroscopic water; the other, that fills the pores, can be gotten rid of by compression, it has been called the interposed water. Linen was found to be more hygroscopic than canvas, and hemp more than cotton.

M. Pettenkofer experimented with a piece of linen and a piece of flannel of equal size and weight. They were first dried at a temperature of 100°C., then exposed together in places more or less damp; after being exposed several hours they were weighed, the variations of weight being noted. He found that the wool was twice as hygroscopic as the hemp; but the hemp absorbed much quicker than the wool, it dried also much quicker.

The quantity of water that can be absorbed by the different stuffs is much greater than is commonly supposed. A woolen garment weighing 5 or 6 kilograms can absorb nearly a litre of water, which will add one kilogram to its weight, and to completely vaporize this water, the body would lose 500 or 600 calories! We know that tissues absorb more when the temperature is low, we also know that when the tissue is wet it conducts much better than when dry, and in consequence protects us much less against the cold; this is the great danger of a damp cold.

It may be asked how wool will protect us more from the dampness than linen, being as it is more hygroscopic? In the first place, because it absorbs and gives off water much slower, and also on account of its indestructible porosity. In proportion as the water fills the meshes and pores of a tissue, the less permeable it will be to the air;

the stuffs that have close meshes, such as linens, cottons, and silks, are affected in this way much quicker than woolen stuffs. The elasticity of the fibres has a great deal to do with the persistence of this porosity; the fibres of wool, even when wet, lose very slightly their elasticity and thus keep the pores from closing, whilst the filaments of flax, cotton or of silk, become softened under the influence of the dampness and offer no resistance to the entrance of water. It is for this reason that wet flannel is so much warmer than wet linen. It is true that silk or linen shirts are cooler than woolen, because they soak up more completely the sweat and let it evaporate.

Hygienists in speaking of the different stuffs, vaguely classify them in the order of their "conductibility," designating by this word the greater or less facility with which they appear to be traversed by heat. They admit that the conductibility decreases in the following order: hemp or flax, cotton, silk, wool. Tissues made of flax, hemp or cotton have the reputation of being the coolest; they are easily wet, and cool the skin by conductibility and by evaporation.

"Linen made of flax or hemp," says M. Bouchardat, "are, of all the stuffs made for clothing, the most favorable for the production of those affections that result from the effect of dampness against the skin."

Cotton stuffs let less heat escape, absorb and retain a part of the transpiration, and cool less quickly by evaporation; their use is more advantageous in general than that of linens. A very widely-spread opinion is that cotton wear is not so healthy as linen or hempen stuff; this opinion or prejudice arises from the fact that it is not so good a conductor, and being prickly with asperity, it irritates more the skin. Examined under the microscope cotton fibres appear angular and stiff, whilst the fibres of flax are round and sleek. Cotton is not suitable in cutaneous affections; in this case wool being more downy and warmer than cotton would be still more hurtful. "It must be from this," says M. Bouchardat, "that the above prejudice originated, and it is the only case where any other substance than flax or hemp, that is well washed, very fine and well rubbed down, could do no harm."

With the above exception, cotton has the advantage of linen, in being warmer for winter, and also during summer, in not allowing the body to cool too quickly. Inhabitants of cold, damp countries should use cotton in preference to flax or hemp stuffs. Wool is more irritating to the skin than cotton, its fibres being so stiff and prickly; the excita-

tion that it produces, when it can be borne, is a therapeutic means that may be used in case where the skin needs a stimulant. Unfortunately the wearing of wool against the skin may become the source of the infirmities for whose cure it is indicated, when from too tender an education, the habit is contracted too soon and without reason. From it will result easily a troublesome predisposition to colds, rheumatism, and neuralgia; the habit when once acquired cannot be given up without danger. But the use of wool is precious in certain countries and in certain conditions of life.

Prof. Brocchi attributes the health and vigor of the ancient Romans to their custom of wearing coarse woolen garments. Woolen garments are considered as excellent preservatives against malaria. In the English army and navy soldiers garrisoned in unhealthy places are obliged to constantly wear wool against their skin, and also to wear sufficient clothing, to protect them from paludean fevers, dysentery, cholera, and other diseases. These measures were found efficacious in protecting the health of workmen raising dykes, opening canals and ditches in marshy ground, whereas before the enforcement of these measures, the mortality from fevers was considerable.

M. Balestra thinks, that in exciting the cutaneous secretions, flannel helps to eliminate from the body the paludean miasms that have been absorbed by the pores, and also to get rid of the deposits that cause rheumatic affections. This hypothesis is confirmed by the singular connection that seems to exist in those climates between rheumatic and intermittent fevers. In addition to which, woolen stuffs, on account of their naps, stop some of the germs carried about by the air, which arrives at the surface of the body filtered and purified. M. Balestra has ascertained this filtering power of thick and shaggy woolen stuffs by direct experiment in paludean regions. It seems useless to add that these protecting garments should be often washed. After woolen stuffs, come cotton, still preferable to linen, because they excite the skin slightly. Silk is also warm to the skin. It will do as a substitute for flannel in winter; it will be borne with difficulty on the skin in summer, because of the excessive heat that it provokes. People inhabiting unhealthy countries should never go out without some woolen covering, in provision of atmospherical changes. It is not less important to be well covered during the night; it is a precaution recommended to all those who live in marshy places.

We are sometimes astonished to see the inhabitants of some hot

countries overcharged with woolen garments: the Arab always covered with his *bournous*, or the Spanish peasant with his cloak, the color of tobacco. These garments protect them from the rays of the sun and from the freshness of the night; they are excellent heat regulators.

The head-dress completes the clothing, as a roof crowns a house. It preserves us from insolation, from cold, and from accidents. A hat should be light and well aired. From the experiments of M. Troupeau, the coolest hats are those made round and conical, they are preferable in hot countries to low-crowned ones. The high silk hat, although not very picturesque, is nevertheless a head-dress eminently hygienic and appropriate to the climates of Europe; it covers the head with a couch of air that protects it efficaciously. As to the feminine head-dress, now-a-days, it is the hair that constitutes the essential part.

The house also, is like a vast and ample garment, destined to regulate our connection with the surrounding medium, and to free us from its tyranny, but not to isolate us from it. It should not, or more likely—for it is too often forgotten—it must not deprive us of air. Happily there is no voluntary prison so well corked that the outside air cannot find access to us without our knowing it.

The fact that water penetrates easily through a wall or ceiling is well known to all the world; the spots that form warn us sufficiently. But the air that comes through cannot be seen, and we imagine naturally that none does come through. It is an error; walls do not hinder us from remaining in communication with the exterior air, even in making no account of the joints of the windows and doors, through which continual currents of air are passing. Anyhow, why should not a subtle gas find its way where water could? We are sure that this porosity of walls is not a misfortune, far from it, as we shall see, it is necessary to keep dwellings from getting damp.

A very simple experiment will serve as evidence of the permeability of constructive materials. Mr. Pettenkofer takes a cylinder of dry mortar, $0^m,12$ long and $0^m,04$ in diameter, coated all over except the two circular bases, with wax, on the two bases are cemented two glass funnels, one of which is prolonged by a rubber tube, the other terminating in a very fine orifice. In blowing in the tube, air is forced through the cylinder, sufficient to blow out a candle placed at the other extremity. In this experiment the air that has passed through the

cylinder is concentrated in the narrow canal of the funnel, and its rapidity is augmented by this.

The experiment can be varied in the following way: On a base, inaccessible to air, is constructed with bricks and mortar a segment of a wall, the anterior and posterior surface of which will be covered with two sheet-iron plates, each having a hole in it, with a tube inserted, the three other sides of the segment receive some impervious covering; if we blow into one of the tubes a current of air will come out of the other. The same result is obtained with wood and the different kinds of stone that will let air pass through them; some other kinds like compact calcarious stone, are only very slightly permeable. It is true that in walls made with calcarious ashlar, water makes up a larger proportion than in brick walls ($\frac{1}{3}$ and $\frac{1}{6}$ respectively) and in this way the equilibrium is established. As a general rule, the more irregular the stones the greater the amount of mortar, and the least regular are the least porous. When wet all these materials become impervious to air. The experiment with the mortar cylinder will no longer succeed after the mortar has been moistened by aspiration in putting the free orifice of the funnel in water. We find also that it is much harder to force water through bricks and mortar, than air; with great difficulty we may be able to make a few drops appear at the free surface. It is then difficult to dislodge water that has entered the pores of a brick; it will only come out by evaporation and very slowly. It will impede the circulation of air in proportion as it fills the pores, and this unfavorable influence of humidity on the permeability of constructive materials becomes more apparent as the grain becomes closer or finer; a remark that has already been made in speaking of the various kinds of stuffs. Thus we see that damp walls allow air to pass through them with difficulty, and M. Märker found that a single day's rain sufficed to diminish, in a striking manner, the coefficient of porosity.

In ordinary weather and when they are very dry, walls transpire; they are incessantly traversed by feeble currents of air, that renew the air of closed rooms, and relieve it of the humidity with which it is charged. The atmosphere of a house is saturated with vapor from the respiration and transpiration of its inhabitants, by the water that is daily used in the household, without counting the dew that is deposited everywhere when warm air from outside penetrates rooms that have remained cold. This humidity that is generated unceasingly, must be

absorbed by the walls so that it may evaporate outside by the action of the sun and wind. It is for this reason that it is a good thing for building materials to be porous and permeable, and not an obstacle to the circulation of the air that should quicken the evaporation. This remark applies especially to northern countries, where the windows cannot be largely opened.

We must be distrustful of the thoughtless innovators who wish to use iron and zinc instead of the stone and wood of our fathers. The imperceptible transpiration of the walls, so important to carry off the dampness, would be suppressed.

The humidity that the walls receive from the external atmosphere in foggy and rainy weather, disappears generally quickly enough under the influence of the wind passing unceasingly over their surface. It is very different with the dampness inside, that is deposited on the walls of badly aired rooms, if the walls are not porous, it is gotten rid of with great difficulty; even heating will not displace it, it will be evaporated by the heat only to be deposited again. This inconvenience is particularly perceptible in recently built houses, whose mortar contains a large proportion of water, and in ground-floors built on damp soil, that becomes impregnated with water by capillarity. This water closes the holes where the air ought to circulate and the wall remains damp, notwithstanding the evaporation that takes place at the surface, and is very harmful to the inhabitants. Damp walls, like wet garments are cold, the water augmenting their conductibility; much heat is also absorbed by the evaporation. From this arises the succession of catarrhs and rheumatism that afflict the unfortunate tenants.

The quantity of water that a recently constructed wall can contain is astonishing. M. Pettenkofer calculated for a house three stories high, five rooms and a kitchen on each floor, say that it took 800,000 kilogrammes of brick to build such a house; the bricks alone would contain 40,000 kilogrammes; the mortar the same amount. We thus find that the masonry of a house of this size would contain 80,000 kilogrammes of water, not an easy thing to be driven out.

Many ingenious contrivances have been invented to dry the walls of newly built houses quickly; the only ones worthy of serious attention are those based on the principles of heat combined with active aeration. The lower the temperature the more air will be necessary. At 10° C. a cubic metre of air, that we must suppose already three-quarters saturated (containing 8 grammes of vapor) can take up only 2 grammes;

to absorb the 80,000 kilogrammes of water contained in the masonry spoken of, it would take 40 million cubic metres of air at 10° C. This volume of air, in a moderate wind could be brought in contact with the exposed surfaces in twenty-four hours; but as it is evident the dampness will only be absorbed in proportion to the rapidity with which it appears at the surface.

Heat combined with a current of air could hasten the drying greatly. In raising the temperature from 10° to 20°C., we increase the evaporation five or ten times; first, because we augment the absorbing capacity of the air (100 centimetres of air, which at 10°C. can only take up 200 or 250 grammes of vapor, can now carry off nearly 1,000 grammes); and, secondly, in raising the temperature we greatly favor the ventilation.

For a dwelling-house, to be safe, its walls should not contain more than 4 or 5 per cent. of free water.

The best way to determine whether the walls are dry enough or not, is first to ascertain the hygrometric degree of the air in the rooms before and after heating.

If the renewal of air is indispensable to insure against dampness, it is still more so to prevent the accumulation of impurities of all sorts that render the air unfit for respiration. All that is necessary to know is, by what signs tainted air is to be recognized, and how much air a man needs to breathe freely in a closed room.

Ordinary atmospheric air contains 21 parts of oxygen and 79 parts of nitrogen, with 0·03 of carbonic acid; carbonic acid then is only found in the proportion of 3 to 10,000. Though the amount of carbonic acid produced by the inhabitants of a large city amounts to many millions of cubic metres daily, the proportion of carbonic acid gets very little above this, thanks to the movements of the atmosphere, and also to the hygienic influence of plants on the atmosphere that take up the carbonic acid freeing the oxygen and absorbing the carbon. Let us see what takes place in a room occupied, such as a school-room. The air changing by the diminution of oxygen, by the pulmonary and cutaneous exhalations, if the ventilation is insufficient, a time will come when the air will be unfit to breathe. It is when the impurities with which the atmosphere is charged become perceptible by their odor, giving rise to the "*malaise*" characteristic of *closeness*. It is generally admitted that when the proportion of carbonic acid has reached 0·001, that this is brought about.

It has indeed been shown that the carbonic acid augments in proportion as the air becomes vitiated, but the malaise that is felt in a close room ought to be attributed to the perishable organic matters that are contained in the pulmonary and cutaneous exhalations. Peclet says that the air coming out of the ventilators of a large hall, full of people, is stinking (*infecte*). The disagreeable odor so characteristic of a close room, is due, according to certain chemists, to a peculiar substance exhaled from the lungs; it has an alkaline reaction and gives off ammonia.

What is really harmful, are these miasmes that smell. The carbonic acid, a relatively inoffensive gas, is only an indication of the progressive change in the air. From the experiments of MM. Regnault and Reizet we know that an animal can live in an atmosphere containing 0·07 of carbonic acid, the proportion of oxygen being maintained at 0·21. We have seen animals perish, when tightly shut up, notwithstanding that the carbonic acid was carried off and replaced by the due proportion of oxygen. Mantigazza has shown that when two birds are placed under two glass bells, and from one he absorbs chemically the carbonic acid, and from the other the organic matters, that the one in the latter resists much longer than the other. M. Pettenkofer was able to breathe several hours in an atmosphere containing 0·01 of carbonic acid without being in the least inconvenienced, but the carbonic acid was not produced by respiration, it was made by a chemical operation.

All this goes to prove that the few thousandths of carbonic acid contained in an atmosphere vitiated by respiration, are not capable of producing the effects caused by such an atmosphere. The oxygen diminishes in about the same proportion as the carbonic acid increases; but the loss of oxygen no longer explains these effects. We may well ask ourselves if a diminution of one per cent. in the proportion of oxygen would be perceptible; would it not be compensated for by a more frequent respiration?

Carbonic acid has often been accused of effects caused by very feeble doses of carbon monoxide or carbonic oxide, coming off from some incomplete combustion, or being reduced from carbonic acid. Carbonic oxide is a true poison, it destroys the vitality of the red blood globules. M. Leblanc found that a dog was asphyxiated in an atmosphere containing ½ per cent. of carbonic oxide and 3 per cent. of carbonic acid, whilst when the carbonic acid was alone used it only produced asphyxia

at 20 per cent. (by volume.) It is to carbonic oxide that the bad effect of cast-iron stoves is to be attributed, as they give it off when their external surface is heated red-hot. Whether the carbonic oxide is due to the permeability of the over-heated cast-iron, to the oxidation of the carbon of the cast-iron, or to the decomposition of the carbonic acid of the air, it has certainly been revealed by analysis, and has given rise to toxic effects, that have been somewhat exaggerated. Carbonic oxide is found in badly prepared illuminating gas, and may become a cause of accidents if allowed to leak

What is the volume of air a man needs to respire freely? This is a very complex question, about which hygienists have had much controversy. It is clear that the answer will depend on outside conditions, and still more on the limit of variation or tolerance, that is admitted for the composition of normal air. Let us commence with the simplest case, staying in a room hermetically sealed. In this case the volume of air is measured by the capacity of the inclosed space, "the cubic space" conceded to each inmate represents at the same time the air which he can dispose of. The air changing little by little, the proportion of carbonic acid will at last reach 0·001, the allowed amount. The larger the space allowed, the longer it will take to reach this dose. The volume of air in such a case must be in proportion to the length of time the room is occupied. This understood, in taking as a base, the proportion of one hundredth of carbonic acid by volume (1 litre to the cubic metre) and admitting that an adult exhales 20 litres from his lungs every hour, we find that the volume of air to be supplied to each individual is 33 cubic metres. Thus—33 cubic metres of air already containing 13 litres of acid (0·4 by cubic metres) in adding the 20 litres furnished by respiration we have a total of 33; the proportion limit 0·001, would thus be reached at the end of the hour. Therefore the cubic space to be allowed to a person shut up in a hermetically sealed place for one hour would be 33 cubic metres, 66 cubic metres for two, etc. More would be necessary if there were lights in the room, a candle alone using as much oxygen as a man; it is true that a candle does not set free so many hurtful products. If a higher proportion limit will be allowed, the volume of air could be much reduced. It must also be remembered that the change in the air takes place by degrees, and only reaches the limit at the end of the hour.

When a closed space (a hall), occupied by a given number of persons

is subjected to a regulated ventilation, a fixed rule is established; the change in the air having arrived at a certain limit, no longer varies; the noxious gases are eliminated in proportion to their production. The cubic space has no other part to play than that of retarding the time when the fixed rule will be established. If it concerns a place that is to be occupied for a fixed time like a dormitory, this consideration will have some importance, for things can then be so arranged that the proportion limit will not be reached before the end of the time of its being occupied. Another consideration is that a small space crowded would need so rapid a change as to cause a draught of air, which is always dangerous.

In calm weather it is not always sufficient to open the windows of places much crowded, such as the ward of a hospital. It is really necessary to have some artificial ventilation. The best ventilators are large open fire places, which, in winter when everything is shut, are lighted and produce strong currents of air, not perceptable to the inmates, from the various cracks of the doors and windows.

SURVEYS FOR THE FUTURE WATER SUPPLY OF PHILADELPHIA.

By Rudolph Hering, C. E., *Assistant in Charge.*

(Concluded from page 237.)

The East Swamp Creek weir is placed at Sumneytown, a short distance below the turnpike bridge, on the land of Daniel Krauss. Similar in general design to the Perkiomen weir, its overflow is 26·02 feet long, and it is loaded only at the ends of the apron. The height above the bed of the stream is nine inches.

The West Swamp Creek weir is at Zieglersville, about half a mile above Leidy's mill, on the land of J. Daup and George Kunkel. The overflow is 68·60 feet long, and height of crest above bed of stream, 15 inches. It was built a little lower than some of the others, as its position is a short distance below a ford on a township road, and it was deemed necessary to avoid raising the water at the ford. At this weir there is a crib below the apron, in addition to the loading at the ends.

The Northeast Branch weir is about one and a half miles east of Schwenksville, on the land of John Alderfer. The overflow is 64·21 feet long. The height of the crest above the bed of the stream is 19

inches. There is no crib at this weir, the height of the crest above the apron allowing it to be loaded with loose stones all the way across.

On November 20th the crest and bed-log below were taken off this weir, and measurements for the season were stopped. This was done to satisfy the land-owner, named Wagner, who lives about half a mile above, and whose farm ford was flooded by the dam. This lowered the water about 12 inches, and no complaints have been made since. Should Wagner wish to use his ford next season, it will have to be raised by building a causeway.

The Macoby weir is at Green lane, a short distance above the turnpike bridge, and differs from the others, as it is built upon rock foundation. It has two overflows or crests placed to form an obtuse angle, the apex pointing up stream. A post placed at the apex divides the crests. The rock was first worked to a level for the bed-log, which was of 6 inch by 8 inch oak. This was bedded to the rock in Portland cement, and bolted down with inch bolts placed five feet apart. The bolts were sunk one foot into the rock, and were fastened with wedges and brimstone. The outer ends of the weir terminated in posts which were set into masonry walls. The walls are three feet thick, and extend into the bank on one side, and on the ledge on the other side of the stream.

The length of No. 1 crest is 14·99 feet; the length of No. 2 crest is 11·82 feet; and the height of the crest above the bed of the stream is 12 inches.

The same general method of measuring the flow at the weirs was used in all cases, and consisted of observations of the height of the water at a gauge placed on a post at a point about five feet up stream from the weir crest. This gauge was carefully levelled upon, and its height compared with the height of the crest, obtained by levels taken at intervals of three feet over its whole length. At the long weirs two posts were used, one at each end, and, when practicable, two observers were employed, one at each gauge, making simultaneous observations. This was of special benefit on windy days, when the water was ruffled more on one side of the stream than on the other. Comparisons between the gauge-posts and the weirs were made at intervals, to note any possible change.

The weir observations have all been tabled on large sheets of ledger paper, and the resulting flows are now in process of calculation.

(*b*). *Delaware Division.*—While gaugings and weir buildings were

in progress on the Perkiomen Division, visits from time to time were made to the Delaware Division, to get general ideas of the water-sheds, and to select sites for gauging points. On August 2d and 3d the Tohickon was explored from Point Pleasant to a point about four miles above Ottsville, and during the week ending August 11th the Big and Little Neshaminy Creeks were explored for several miles above their junction at Warner's ford; on August 19th another visit was made to the Neshaminy, and on August 27th a trip was made to Point Pleasant, at which place it was decided to build a weir upon the Tohickon.

Work was begun upon the Tohickon weir September 12th. Regular gaugings of the height of the creek began September 13th, and estimates and gaugings of the flow were made at intervals from August 1st, beginning regularly September 25th, at the weir.

Observations of the flow of the Big and Little Neshaminy were made at intervals from September 13th, and regular gaugings of the height of the Big Neshaminy began at that time.

Meter measurements of the flow of the Big and Little Neshaminy Creeks at a point below their junction at Warner's ford were made, beginning September 28th, and continuing regularly till the completion of the Neshaminy weir.

Work began on the Neshaminy weir October 4th, and regular measurements began November 7th.

The weir on the Tohickon, at Point Pleasant, is located a short distance below Stover's Mills, on Mr. Stover's land. It is built on rock in a manner similar to the Macoby weir. The crest is 43·73 feet long, and walls of masonry, about four feet in thickness, built of stone found in the bed of the stream, extend into the banks on either side. Shortly after the weir was completed the volume of the stream increased considerably, and the weir crest was raised four inches higher to properly back the water on the up stream side. This should have been done at first, but the location of the weir so near the race-way of the mill above caused the proprietors to fear that it might interfere with the running of their wheels, and the weir was built as low as possible. They, however, have never complained of the additional height, and probably have never noticed it. The height of the weir, with its four inches additional crest, is 16 inches above the bed of the stream.

The Neshaminy weir is located on the Big Neshaminy, a short distance below the iron bridge at Warner's ford. It is built on rock,

and consists of a bed-log of 10 in. x 12 in. oak timber, bolted to the rock. Between the bed-log and the ledge is a wall of Portland cement masonry, varying in height from 6 inches to 3 feet, the latter being the depth at a pocket in the ledge, at one end. The bolts are sunk into the ledge at least one foot, and pass up through the wall above, into the bed-log. They are one inch in diameter, and about four feet apart. The crest-pieces are fastened to the upper side of the bed-log, and at each end of the overflow is a post, sunk into a wing of masonry which extends into the bank. The length of the crest is 66·79 feet, and the height of the crest above the bed of the stream is 17 inches.

Flash-boards were used at all the weirs in times of very low flow, to shorten the crests and to confine the flow to observable limits. They were made of inch boards, and were fastened to the crest with iron hooks or dogs, so arranged that they could be readily put on or taken off, as occasion required.

The owners of the lands on which the various weirs are placed were in all cases consulted, and their consent to build the weirs obtained before construction began.

The difficulty of finding laborers delayed the construction of most of the weirs. Most of the localities in which the weirs are placed are isolated, and labor was engaged to a great extent from neighboring farms. In the case of the Neshaminy weir more than a week passed, and several gangs of men were engaged, before one was secured that would go to work.

(c). *Lehigh and Upper Delaware Divisions.*—It was considered desirable to gauge the minimum flow of the Lehigh and Delaware Rivers, and this was done in September with the Department meter. The Delaware was gauged at two points: on September 15th and 16th, at a place about one and one-half miles above Portland; and on September 20th, at another point nearer the Water Gap, above the steamboat landing. The Lehigh was gauged at White Haven, just above the upper end of the upper mill pond, on September 19th.

The results of these gaugings show the minimum flow to be as follows:

Delaware River,	September	20th,	697,000,000	gallons	per	24	hours.
Lehigh	"	"	19th, 76,000,000	"	"	"	"

At both places well defined points were made, and the heights of the water noted in connection therewith.

(*d*). *Meter Measurements.*—During certain of the high flows that have occurred since August 1st, meter measurements have been made in the Perkiomen and East Swamp Creek. The Perkiomen was metered on August 2d at a point about 500 feet below the foot-log above Green lane, and the station used for metering East Swamp Creek was at the railroad bridge below Perkiomenville, near the junction of East Swamp Creek with the Perkiomen. As a rule the weirs did not fail to act as such during the high flows, and as the rise and fall of the streams occupies but a few hours during summer storms, it would not be practicable to get meter measurements at the point of maximum flow of all of them.

A staging has been attached to Leidy's bridge to use for gauging the West Swamp Creek, but use has not yet been made of it.

In the Delaware Division several storms occurred during October and November which occasioned too great a flow for the Tohickon weir to carry. The rise and fall of the water was carefully noted, and estimates of the flow will have to be made, as no means of taking meter measurements existed. On the Neshaminy the storms caused increases of flow sufficient to temporarily stop work on the weir. Permission was obtained from the Bucks County Commissioners to build stagings under the iron bridge at Warner's ford, but it was decided to wait till next season before building them.

No rating curves of the current meters were in the possession of the Water Department, and they were therefore rated in November at the Fairmount Reservoir, where the water was lowered to a convenient level for the purpose. The rating was done in this manner: The meter was secured to a stiff rod, and the observer, holding it as nearly plumb as possible in the water, walked along the stone curbing, which was but a few inches above the water in the reservoir. The distance through which he walked was divided into lengths of 25 feet, and a second observer noted the time at which the meter passed each point. In this way a record of the steadiness of the motion was made, as well as the velocity. A third assistant, walking behind the assistant with the meter, carried the battery and the register, and noted the number of revolutions. When a sufficient number of experiments at different velocities ranging from 0·3 to 5 feet per second had been obtained, rating curves were plotted, which are now in use.

RAIN GAUGING.

A number of rain gauges of the Signal Service pattern were procured, and placed at various points during the season, as follows:

Zieglersville	July 16
Green lane	July 24
Ottsville	Sept. 1
Pennsburg	" 9
Doylestown	Oct. 5

The gauges at Zieglersville and Green lane were in charge of the party. The gauge at Ottsville was placed in charge of Rev. G. W. Roth, that at Pennsburg in charge of G. H. Hart, and that at Doylestown in charge of Thomas Walton.

Since the party left the field (December 15th), the gauge at Zieglersville has been transferred to Frederick, at a point about three-quarters of a mile from its former location, and is in charge of J. G. Hillsman; the gauge at Green Lane, after freezing and bursting, has been repaired, and is at present in charge of N. S. Renninger.

Automatic Rain Gauges.—Three of these instruments, after the Draper pattern, were ordered to be made during the summer. They are designed to give a continuous graphical record of rain storms, showing the time of beginning and ending, the variations in the rate of the rain fall, and its amount. These gauges were placed at the following points:

No. 1. Thirteenth and Spring Garden Streets.
No. 2. Green Lane.
No. 3. Doylestown.

They were put in operation upon the following dates:

No. 1. September 11th.
No. 2. October 23d.
No. 3. October 18th.

The delay in getting gauge No. 2 into operation was due to difficulty in getting a carpenter to do the necessary work, and to the fact that after it was put in place the clock-work was found to be out of order, and time elapsed before a man could be found to repair it. It has not been in operation since December 15th.

In the case of gauge No. 3, it was originally intended to place it at Ottsville, as being, topographically, a desirable point. This place,

however, was so far away that an opportunity to set up and regulate the gauge did not occur, and it was finally placed in a green-house at Doylestown, where it was expected that the heat from the boilers would melt the snow falling in winter sufficiently fast to insure its efficient working.

The gauges were found to work well as a rule, and tests showed their construction to be good and to warrant accurate results.

Rain gauge observations are in constant progress at the points above mentioned, and in the tabulated reports accompanying this will be found additional records from other points, having some connection with this investigation.

During the first week in December, the crests were removed from the different weirs in both divisions, gaugings ceased for the winter, and on December 15th, the party reported for duty at Philadelphia.

Measures were taken to continue observations of the flows of the streams through the winter months, as follows:

The steam-gauges on the Perkiomen are to be read twice a week, and in case of high flows, often enough to give the maximum heights. These readings are to be taken by J. G. Hillsman.

The gauge above Longaker's dam is read every day by J. Wisler.

The stream gauge on the Tohickon, at Point Pleasant, is observed in the same way as the Perkiomen gauges, by R. C. Stover, and the Big and Little Neshaminy stream gauges are observed by John Kirk.

The dam at Schwenksville, known as Longaker's, has been carefully levelled upon in order that a section of flow in connection with the gauge above the dam can be calculated. The water from the Perkiomen, the Macoby, East Swamp and West Swamp creeks, passes over this dam.

The party is at present at work upon the calculations for the summer flow, but as considerable remains to be done on the calculations of the heavy flows, the averages for the season have not yet been determined.

Very respectfully,

C. S. Gowen,

Assistant in Charge of Hydrographic Work.

C. SANITARY SURVEY OF THE SCHUYLKILL VALLEY.

The work done under this head comprised an inspection of the water-shed for the purpose of ascertaining the various elements contributing to the pollution of the Schuylkill water. Mr. Dana C. Barber, C. E., was placed in charge of the investigation. He entered upon duty December 15th.

As it was winter, the ground covered with snow, and the streams frozen, it was not possible, besides making a general inspection of the water-shed, to do much more than gather information from the local authorities, and from persons in charge of the establishments contributing to the pollution of the streams, which part of the investigation is about completed. An original estimation or gauging of the quantities of objectionable matters was attempted only where a fairly satisfactory result could be obtained.

The territory was, for convenience, divided into seven districts, the lower ends of which were just above the principal towns, viz., Reading, Pottstown, Phœnixville, Norristown, Conshohocken and Manayunk, and Fairmount Dam. On the completion of the investigation, therefore, it will be possible to state the total amount of pollution at the water in-take of each, excepting Pottstown, where the local supply is now derived from a point on the river below the town.

The report of Mr. Barber, a summary of which is appended, gives an account of his researches in full. He begins at the headwaters of the Schuylkill river, and follows it down to Fairmount Park. The Perkiomen water-sheds above Schwenksville and the Wissahickon valley were not included; the former, because the surveying parties had already been over the ground; the latter, because time did not permit.

The report gives a brief account of the respective water-sheds. The amounts which represent the quantity of domestic waste water, and the disposition of the sewage and excrementitious matter, are carefully stated.

The manufactory waste is given wherever it could be ascertained. It is exceedingly difficult, however, and in many cases impossible, to determine the exact amount of waste water reaching the river. Nothing more can be done in such cases than to record the amount of material used in the various industries, and, by analogy with other similar works, judge of the probable amount of waste. Gauging the effluents

from the establishments, together with chemical analysis, would give the best answer to this question, and it should hereafter be done in the most important cases.

In a few instances, purification of the waste water has been attempted. The sewage from the State Asylum at Norristown is precipitated in tanks, and subsequently filtered, before it is discharged into Stony Creek. Seville Schofield, Son & Co., of Manayunk, and J. & J. Dobson, of the Falls, utilize their waste from wool scouring. The Campbell Manufacturing Company, of Manayunk, filter their dye-house waste water. The efficacy of their processes to purify the sewage and waste waters should be examined into next summer.

Inquiries were also made regarding the death and sick rates in the towns along the river, especially with regard to zymotic diseases; but the absence of Health Boards or Officers made a complete result impossible. Dr. R. S. Keelor has furnished a valuable contribution on this question in relation to Phœnixville. Dr. Chase kindly gave the health statistics of the Norristown Asylum. The United States Census Reports also furnish data on this subject.

The information collected, considering the short space of time devoted to it and the season, is very satisfactory. Some time yet will be required to record the conditions during the summer months.

An examination should be made into the nature of the soils underlying the towns along the river, in order to determine their filtering capacity, and into the disposition of the night soil about the large towns, as well as into the approximate amounts of fertilizers and manure used on the river slopes. To ascertain, if practicable, the quantity of mine water and its acidity would be of value in connection with its neutralization by the lime water above Reading. Further investigations likewise are necessary regarding the pollution from the Reading Gas and several other Works, where at present only imperfect information has been obtained.

The comparative fulness of Mr. Barber's report is largely due to the facility afforded and assistance rendered by the proprietors and managers of almost every manufactory in the valley, many of whom went to considerable trouble in order to give the desired information promptly and thoroughly. In many of the smaller woolen mills, however, considerable difficulty was experienced in obtaining the quantities of materials used; but nowhere, with the single exception of the

Albion Dye Works, in Manayunk, was the desired information positively refused.

Special assistance in compiling the appended statement was furnished by

William D. Pollard, Esq., Secretary and Engineer, Pottsville Water Company.

A. Harvey Tyson, Esq., City Engineer, Reading.

D. F. Reinert, Esq., Borough Surveyor, Pottstown.

Edwin F. Bertolett, Esq., Borough Engineer, Phœnixville.

R. S. Keelor, M. D., Phœnixville.

Alex. K. Calhoun, Esq., Borough Surveyor, Norristown.

D. GEOLOGICAL SURVEY.

Mr. R. H. Sanders, geologist, made the investigations of the geological features of the water sheds and conduit lines.

The reports of the Pennsylvania Geological Survey, Professor J. P. Lesley in charge, furnished valuable information. The line of the Delaware conduit from Kintnersville to the Water Gap is fully described, also the Perkiomen conduit, as far as Norristown, and those portions of the Berks and Lehigh counties which are situated in the Perkiomen water-shed. The geology is alsc mapped along the proposed Lehigh conduit as far as the Lehigh Gap.

Mr. Sanders has so far examined only the line of the Delaware conduit. Prior to recording them on the profiles after these shall have been finished, he describes the formations along its course in general, as follows: "From the Frankfort reservoir to one and one-fifth miles south of the crossing of the Bound Brook Railroad the conduit line traverses a micaceous gneiss, rotten near its surface, from one to fifteen feet deep. From the reservoir to near the Pennypack creek it is covered with gravel, and thence up the valley with soil from one to ten feet deep. On the next half mile is found a hard, massive gneiss coming well to the surface. South of the creek hard, hornblendic rock shows for thirty feet. To the north of it the line passes over mica slate covered with about ten feet of soil, for a distance of fifteen hundred feet; the rock itself is rotten in some places to the depth of ten feet. On the remaining distance to the Bound Brook Railroad chlorite slate is found.

"The Paul's Brook valley, in which the Bound Brook Railroad

crosses the conduit line, first shows limestone for three hundred feet, then sandstone and slate. Over the limestone there is a swamp. From this valley, for about a mile, hard gneisses again appear at the surface. The next fifteen hundred feet shows syenite, sometimes covered with broken rock and loose material from ten to twenty feet deep. Following this, for two thousand feet, is gneiss, mostly hard and massive, but with a few layers of rotten rock extending to a depth of twenty feet. Again syenite appears for about thirty-five hundred feet. It is generally massive and hard, but rotten in places to a depth of five feet. It is covered with from five to ten feet of soil. Thence, up to the Forks of the Pennypack, the syenite, which still continues, is covered with gravel. For fifteen hundred feet above the Forks the rock is probably a horizontal, thin-bedded sandstone, covered with about five feet of soil. After this the Danville sandstone and slates appear, but mostly the latter. The sandstone is thin-bedded and friable; the layers are about horizontal. The same formations extend as far as the Neshaminy creek. At the latter the shales begin to crop out, and continue to the Forks. Near this point they reach twenty feet above the creek, and are overlaid by sandstone. Here the rocks have a slight dip to the northwest.

"At the point where the conduit crosses the Neshaminy the bed rock is slate. The latter extends up the Mill Creek valley, dipping fifteen degrees north, thirty degrees east. Then follows sandstone for several hundred feet, and farther on, for about the same distance, slates appear. Sandstone again forms the rock as far as the Buckingham township line, and dips slightly to the north.

"For the next two miles we find shales and slates, with not over fifty feet of sandstone. The following half mile shows massive, hard sandstone, which is covered with loose material for several feet.

"From a point three-quarters of a mile south of Centerville to one a few hundred feet south of Greenville, limestone appears and is covered with from one to twenty feet of clay. It is followed to the Solebury township line by a coarse conglomerate sandstone. Here red shale crops out; it is but a few feet thick, resting on massive sandstone, which extends down to Centerville. From the mill below Centerville to Lumberville the rocks are alternating layers of slate and sandstone, dipping ten degrees to the northwest. From the Plumstead township line, for fifteen hundred feet north, there is massive red sandstone; then, for a thousand feet, altered slate rock, a very hard mate-

rial to quarry. This is followed by fifteen hundred feet of trap, and again by altered slate to a point about half a mile beyond Point Pleasant. The following two thousand feet show sandstone, then fifteen hundred feet of slates.

"Altered slates, with a small amount of trap, once more appear for about a thousand feet. The next mile and a quarter brings slate, with a small amount of sandstone, succeeded by fifteen hundred feet entirely of sandstone. From here, passing Erwinna to the Roaring Rocks, slates and shales are found, with a few feet of sandstone; then a large mass of trap, extending down below the grade line of the conduit, is found to extend as far as half a mile south of Kintnersville. By keeping the conduit nearer to River Bluff, between Uhlertown and Kintnersville, the trap rock could be avoided, and the tunnel would pass through alternating beds of slate and sandstone, but be about half a mile longer. From the end of the trap down to the run which passes Kintnersville, the rocks are slates and shales.

From this point to the Water Gap the State Geological Survey covered the ground. From the map in Report D, 3, we find the following general profile:

One mile of gneiss, one and a half miles of limestone, one mile of gneiss, two and a half miles of limestone, two and a half miles of gneiss, then again limestone as far as Easton. From Easton, for two miles up the river, occurs limestone, and then, for a mile and a half, gneiss, serpentine, etc. Limestone then appears as far as Belvidere bridge, and up to one quarter of a mile south of Portland we find slates. Extending to half a mile north of Portland is limestone covered with gravel. From here to the Water Gap are slates, and the Gap itself shows hard massive sandstone.

In making the reconnaissance of the Lehigh water-shed above White Haven, Mr. Berlin found that the rock consisted almost entirely of Pocono sandstone and conglomerate, with an occasional outcrop of red shale, making, therefore, an excellent formation for the gathering of water.

The rocks in the Perkiomen water-shed are estimated by Mr. Sanders to be five square miles of limestone, twenty-five miles of quartzites and the remainder red sandstone and red shales with some trap. The water divide from Green Lane to within two miles of the South Mountain is made by a trap dike which has altered the red Shales on

each side of it for about one thousand feet. The rocks in the upper Perkiomen are mainly horizontal.

About sixty square miles of the Perkiomen water-shed have been carefully investigated by the Pennsylvania State Geological Survey, Vols. D, 3. Large areas of the Delaware and Lehigh water-sheds above the respective "Water Gaps" have also been reported upon in detail.

Prof. James Hall, Geologist of the State of New York, has communicated to the Department geological data regarding the Delaware water-shed in that state. The affluents have their origin chiefly in the Catskill or Old Red Sandstone formation. It is quite uniform in character, consisting of coarse and fine sandstone with shaly partings or with intervening beds of shale. A large portion of the area is still a wilderness, or but very sparsely settled.

Special thanks are due to Prof. J. P. Lesley, for advance sheets of maps and reports issued by the Geological Survey.

E. COLLECTION OF SAMPLES.

Samples of water for analysis were from time to time collected and forwarded to Prof. A. R. Leeds. The manner of the collection was in accordance with the instructions received from him.

The samples collected on the Perkiomen were from Perkiomen Creek at Green Lane, at Frederick and near its mouth; West Swamp Creek at Zieglersville; Macoby at Green Lane; East Swamp Creek at Perkiomenville; North East Branch near Schwenksville; Skippack at Evansburg, and Stony Creek at Norristown. All water from these localities would have to be impounded.

On the Delaware water-shed the samples were taken from Pennypack at Shelmire's Mills, Big and Little Neshaminy at their junction, Tohickon and Haycock Creeks above their junction, and Tohickon Creek at Point Pleasant,—all of which water requires impounding. Samples were also taken from the Delaware river at Point Pleasant and at the Water Gap.

Samples of water also collected from the Lehigh river at White Haven, and the Tobyhanna above its mouth, representing the quality to be obtained by the Lehigh project.

Finally, samples were collected from the Schuylkill river above Phœnixville, and from the Roxborough and Fairmount pools.

Hand specimens of some of the rocks situated along the lines of the proposed conduits, especially near the tunnels, have been filed at the office.

Boiler scale has been obtained from various localities over which the surveys have extended.

F. OFFICE WORK.

As the fair weather continued almost to the end of the year, and the surveys were carried on as long as possible, very little office work has yet been done.

Quarters were obtained, by authority of the Department, December 20th, at 925 Walnut street, and after a short leave of absence during the holidays, the party began working up the field notes.

The topography along the conduit lines is being plotted to a scale of 200 feet to the inch, and the general water-sheds to a scale of 400 feet to the inch. The latter is finally to be reduced to the scale 1,600 feet to the inch, of the topographical maps of the State Geological Survey, which cover 63 square miles of the Perkiomen water-shed.

The topography will be indicated by 5 feet contours on the conduit plan, and 10 feet contours on the general plans.

A preliminary map has been compiled, on a scale of $4\frac{3}{4}$ miles to the inch, from the best accessible sources, covering the entire Delaware, Lehigh, and Schuylkill water-sheds, to be used for general purposes. Four copies are attached to this report: one showing the areas covered by the surveys of last year; a second, the stations where the streams have been gauged and the rainfall observed; a third and fourth give the rainfall for the third and fourth quarters of the past year.

A general map, comprising the Perkiomen, Tohickon, and Neshaminy water-sheds, and the territory as far south as the city, on a scale of one and a half inches to the mile, will soon be commenced, and the surveys as finished will be plotted on it.

The hydrographic work is being tabulated and compiled.

I beg to make special mention of the industry with which the members of the survey parties have pursued their work during the last season, and especially of the skill with which Messrs. Gowen, Linton, Paddock and Barber have conducted their respective branches of the investigation. The amount of work accomplished during the time spent, as the preceding account shows, is very large and satisfactory.

G. WORK REMAINING TO BE DONE.

The inquiry in regard to a future water supply is of great magnitude, owing mainly to two causes. One is the favorable development of the Point Pleasant scheme, as compared with the Perkiomen; the other is a favorable conduit line from the Perkiomen basin to White Haven, as compared with the Delaware conduit from Point Pleasant to the Water Gap.

Neither of these projects has been seriously considered heretofore. It will not require much additional work to ascertain the main features of the Lehigh conduit line, because the topography of most of the territory is already mapped. But to properly judge of the practicability and advisability of using the Tohickon and Neshaminy water, and of storing it, surveys must be made of these two water-sheds with the same care as those of the Perkiomen valley.

The surveys then in the City's possession would cover the entire ground from which it is possible to obtain water by a near gravity supply. The additional territory to be considered naturally increases the cost of the investigation, yet the sum required is not out of proportion to the expense found necessary in other cities. Boston was obliged to spend about $60,000 for the preliminary investigation for its additional water supply, and New York has expended about $250,000.

The Commission of Experts (1883) say: "Indeed, in other cities large sums are annually expended for surveys to secure fresh information respecting the possible sources of water supply."

To carry the contemplated work to completion would certainly be economical, as the surveying parties have become thoroughly acquainted with the territory and the work, and the final result, as well as the benefit from the sum already expended, could be reached earlier than if the completion were postponed.

To accomplish this the following information will still have to be obtained, after the surveys of last season have been worked up:

Perkiomen Project.—Three square miles of topography for storage basins and conduits.

One hundred and thirty square miles of general topography, to ascertain the physical, commercial and sanitary features, including East Swamp Creek, North East Branch and Shippack valleys.

Sixty-three and three-tenths square miles of water-shed, already contoured and mapped by the State Geological Survey, to be inspected to ascertain its commercial and sanitary features.

Geological examination of the water-shed and the proposed conduit line.

Estimation of land and other damages for conduit and storage basins.

Completion of the statistics of polluting elements in the respective valleys affecting the condition of the surface water to be impounded.

Continuation of the hydrographic work in the basin throughout the year.

Respecting the Lehigh extension, certain parts of Kidder, Penn Forest, Sterling and Dreher townships have not yet been inspected, and a careful reconnoissance at least, is yet to be made of the left bank of the Lehigh, from Mauch Chunk to Catasauqua, for a conduit line.

The collected maps and surveys of the Lehigh water-shed and conduit line remain to be compiled and a general estimate made of the latter from the Perkiomen to White Haven.

Delaware Project.—Five square miles of topography for storage reservoirs in the Neshaminy and Tohickon water-sheds.

Three square miles of topography for alternate conduit lines.

Two hundred and thirty square miles of general topography of the Neshaminy and Tohickon water-sheds, to ascertain their physical, commercial and sanitary features.

Geological examination of the Neshaminy and Tohickon basins.

Estimation of land and other damages for conduits and storage basins.

Compilation of the statistics relating to the condition of the surface water to be impounded.

Continuation of the hydrographic work throughout the year, and of the analyses at important points and times.

Schuylkill Valley.—Completion of the Sanitary Survey of the valley.

Collection of data as to means and cost of guarding against future pollution, by local restrictions and purification works, or by intercepting sewers.

Measurement of the flow of the river by more careful means than heretofore.

Artesian Wells.—Geological examination and borings to ascertain the probable extent of water-bearing strata about the city.

Very respectfully,

RUDOLPH HERING,

Assistant Engineer in Charge.

"THE EARTH'S ELLIPTICITY."

By Pliny Earle Chase, LL.D.

In the July number of the Journal of the Franklin Institute, Prof. d'Auria has amended his first paper on the Ellipticity of planets, by introducing some of the omitted elements to which I called his attention,* and thus obtaining Newton's value for e. Through the hypothesis that polar and equatorial gravitation were equal when the earth's ellipticity was determined, a hypothesis which seems to me altogether untenable, he gets a value nearly identical with Listing's.

In his letter to the Editor (p. 152) he shows, by virtually charging me with begging the question, that he totally misunderstands my reasoning. I do not "accept Newcomb's [Listing's] estimate of the ratio of centrifugal force to attraction at the equator;" but I show that the probability of that estimate is confirmed by the closeness of its accordance with a result which is indicated by known equilibrating tendencies. The centrifugal and centripetal relations which he represents by j and k, being constantly operative, the calculation may be simplified by considering their joint efficiency, instead of treating them separately and modifying one of them hypothetically, so as to bring about an accordance between theoretical and observed values.

Let w_0 = angular velocity of free revolution at earth's equatorial surface, or self-sustaining velocity under combined centrifugal and centripetal tendencies, w being angular velocity of terrestrial rotation. Then $\left(\frac{w}{w_0}\right)^2$ = combined tendency of j and k to compress the terrestrial spheroid. If the earth were at rest we should have $\left(\frac{w}{w_0}\right)^2 = e = 0$ and the form would be spherical; if $w = w_0$, we should have $e = 1$ and the form would be that of a flat disk. The actual value is $\left(\frac{w}{w_0}\right)^2 = \frac{1}{288{\cdot}4}$. The most recent estimates of $\frac{1}{e}$ are the following:

Fischer	1868	288·5
Listing	1872	288·5
Jordan	1878	286·5
Clarke	1880	293·5

* *Ante*, p. 20.

I can think of no principle which is more likely to produce and maintain such closeness of accordance than that of "the flow of solids." In each oscillation of semi-gravitating rotation the sum of the gravitating accelerations, gt, represents a centrifugal tendency $(16{\cdot}98\pi)^2$ times as great as that of mere rotation. Prof. d'Auria may, perhaps, find in this fact and in the immense energy of æthereal oscillation a fruitful field for the exercise of his skill in mathematical analysis.

The harmonic connection of Neptune's mass with that of the earth, seems to be dependent upon the fact that æthereal waves, as well as all other waves, tend to maintain the velocity, $\sqrt{gh}$, which is due to the place at which they originate. The value for the reciprocal of earth's mass, 327994, which was given in the May number of the JOURNAL, was based upon the hypothesis that the earth's orbit was circular; the modified value, 329196, made allowance for the secular orbital eccentricity.

LENGTHS OF INDICATOR CARDS.

By ROBERT GRIMSHAW.

For convenience in reference, I have arranged a table showing at a glance the length of diagram that will be given where the point of attachment of the cord to the main motion lever is $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, etc., as far from the pivot as the distance from the pivot to the point at which the vibrating link is attached to the main lever.

Thus: For indicating an engine of 20-inch stroke, if the "pendulum" is 43 inches long between stationary and swinging centres, if you attach the card $\frac{1}{6}$ of the distance of 43 inches from the fixed centre, you get a card 3·33 inches long. If you attach it $\frac{1}{5}$ the distance, or 8·6 inches, you get a card 4 inches long; and if you attach it $\frac{1}{4}$ the distance, or $10\frac{3}{4}$ inches, you get a closed tracing 5 inches long.

One-fifth the distance would be most convenient on a Thompson or a Tabor machine, or any other instrument having a big barrel, if the speed is not too great, and $\frac{1}{6}$ on a "Crosby No. 2."

It is just as well to have the lengths known beyond any possibility of error in the hurry of calculation; as it is mortifying to find a card

so long as to lap on the barrel and break the pencil point; and it is generally desirable to get as long a card as the speed will allow.

Table of Lengths of Indicator Cards.

Stroke of Piston.	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4
Inches.									
4	.....	.....	.....	.....	.....	.....	.....	.....	2
5	.....	.....	.....	.....	.....	.....	.....	1·67	2·5
6	.....	.....	.....	.....	.....	.....	.....	2	3
7	.....	.....	.....	.....	.....	.....	1·75	.....	3·5
8	.....	.....	.....	.....	.....	.....	2	.....	4
9	.....	.....	.....	.....	.....	.....	2·25	.....	4·5
10	.....	.....	.....	.....	.....	2	2·5		
11	.....	.....	.....	.....	.....	2·2	2·75		
12	.....	.....	.....	.....	2	2·4	3		
13	.....	.....	.....	.....	2·17	2·6	3·25		
14	.....	.....	.....	2	2·33	2·8	3·5		
15	.....	.....	.....	2·14	2·5	3	3·75		
16	.....	.....	2	2·28	2·67	3·2	4		
18	.....	2	2·25	2·57	3	3·6	4·5		
20	2	2·22	2·5	2·86	3·33	4	5		
24	2·4	2·67	3	3·43	4	4·8			
30	3	3·33	3·75	4·3	5				
36	3·6	4	4·5						
40	4	4·44	5						
42	4·2	4·67							
48	4·8								

Of course the higher the speed the shorter the card must be, both to prevent "flinging" at the ends and to allow a convenient "pull-out" for hooking on.

Volcanic Interruptions of Telephones.—During the eruption at Krakatoa, telephonic communication was almost impossible at Singapore, the words being drowned by a singular noise which sounded, on a subterranean cable of 1½ kilometers, like pistol shots. The distance between Singapore and the Strait of Sunda, is about 800 kilometers, (497·11 miles). The phenomena seemed to be of an electric nature, rather than acoustic.—*Lumière Electrique*, May 3, 1884. C.

SIEMENS' REGENERATIVE GAS BURNERS.

By CHAS. E. RONALDSON, M. E.

[Read for the Author, by the Secretary, at the Stated Meeting held Wednesday, June 18, 1884.

While many improvements in electric lighting have been going on within the past few years, many efforts to improve the quality and the appliances for burning gas have been also made, various burners have been devised, but few of them have been found to possess decided merits, or have come into general use.

Quite lately, however, a decided step in advance has been made, in the construction of a burner for illuminating gas, which involves certain novel, and scientifically correct, principles in its design, and which has so fitly demonstrated its superiority in point of economy and quality of light afforded, that, although but a comparatively short time has elapsed since its first introduction in this country, it has come into very general use, and it is probably simply a question of time when it will be as widely and favorably known and used in the United States as in Europe. The burner referred to, is the Siemens' Regenerative Gas Burner, the invention of which is due jointly to the late Sir William Siemens and his brother Frederick Siemens, of Dresden, although it has been perfected by the latter, who describes the principle of his burner as consisting in heating to a high degree, both the air and gas previous to their combustion, and utilizing for the purpose the heat still remaining in the waste products of combustion.

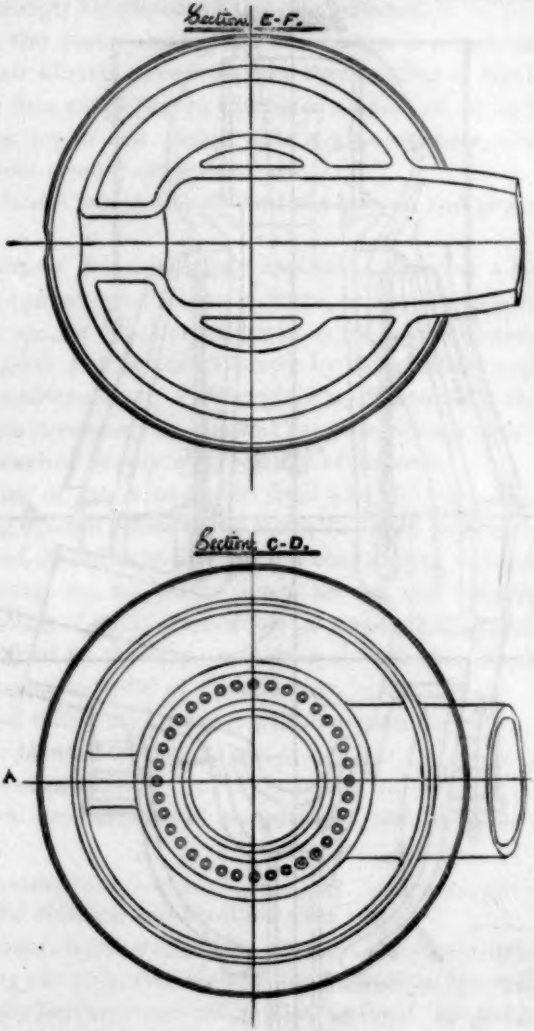
The great merit of these burners resides in the fact that they afford a powerful illumination but at a greatly diminished consumption of gas. They are made to yield 10-candle power per cubic foot of gas burned, while the ordinary burners yield only from 3 to 4-candle power. At the same time, they act as excellent ventilators, when used in-doors.

The accompanying illustrations correctly exhibit the construction and operation of these burners, viz.:

A vertical section on the line *A B*; and two horizontal sections upon the line *C D* and and *E F*, show the air chamber, the gas chamber with the tubes at the top of it, and the outside casing.

The action is as follows: The gas passes into its chamber from the pipe at the bottom of the burner, thence up the tubes, meeting at the

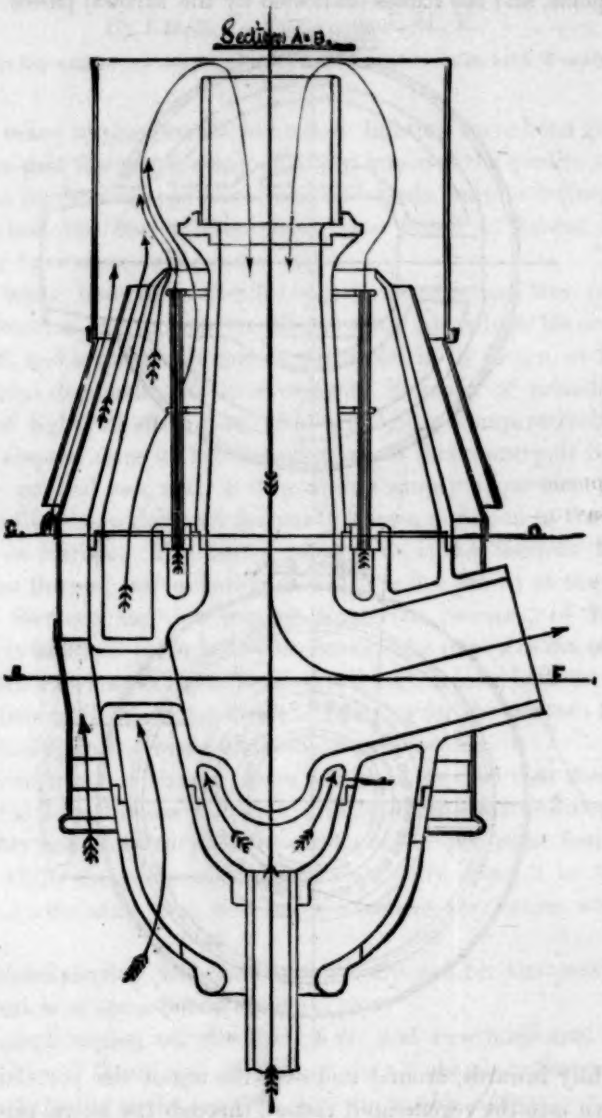
point of exit, the proper proportion of air which has likewise passed from below, up through its chamber to the top. Ignition takes place at this point, and the flames (indicated by the arrows) passes upwards



and slightly inwards, around and over the top of the porcelain cylinder, down into the regenerator, thence, through the lateral pipe, to the chimney.

The heat thus generated is absorbed in its passage through the

regenerator, and is in turn taken up by the currents of cool gas or air entering their respective chambers, heating them to above 1,600°F.;



the estimated temperature of the waste products of combustion in the regenerator. The illuminating effect is thus enhanced, and the largest

available quantity of heat and light produced from the combustion of gas in the atmosphere is obtained.

As the chimney and side pipe become heated the draught is keener, and the thorough ventilation of the room effected.

Between the metal casing and the burner is a space where a cool current of air ascends, preventing the over-heating of the burner, and at the same time supplying an additional amount of air to the flame.

Upon the top of this casing rests a glass cylinder, which protects the flame from counter currents of air.

A few minutes will suffice to heat the burner, and produce the best effects.

These burners are particularly applicable wherever a large amount of light is required, whether for in-doors, as for churches, hotels, mills or factories, etc., or out-door purposes, as for streets, stations, etc.

Equally good results are obtained by using either coal or oil gas, and late experiments in Pittsburgh, Pa., demonstrate the fact that these burners consumed the natural gas economically, and with a success unapproached by any other variety of burners.

The saving of gas amounts to from 35 to 50 per cent., while the illuminating effect is about three times the light produced in the best Sugg-Argand of ordinary size, the gas consumption being equal.

In summing up, the claims made are not over-estimated, and the following points of merit are deduced, at one time indicated by theory, but now verified by the most practical and rigid tests, viz.:

Unapproachable power of illumination.

Diversified utility for "intense" illumination.

Economy in consumption of gas.

Complete combustion.

Utilization and disposal of the products, and the waste products of combustion.

Absolute steadiness.

Admirable diffusion and excellent ventilation.

The Siemens' Regenerative Gas Burner Company are at the present time making the following sizes of these burners, but will shortly be able to supply burners consuming 100 cubic feet of gas per hour, having a candle-power of 1,200.

Size.	Gas Consumption.	Candle Power.
I	45-50 cubic feet.	450 to 500
IIa	35 " "	300 to 350
II	25 " "	200 to 250
III	14 " "	100 to 125

APPENDIX.

The following tables are copies from the official records of trial tests made with the Siemens' Regenerative Burner by a number of the New York gas light companies. The figures will tell their own story. —C. E. R.

The New York Gas Light Company, New York, January 18, 1883.

DATE.	Standard of gas and burner. Bray's U. S. No. 7.						Friedr. Siemens' Reg. Burner.					
1883.	Candle power.	Specific gravity.	Gas consumed per hour.	No. of burners.	No. of experiments.	Duration of test. Min.	No. of observations.	Pressure on burner.	Gas consumed per hour.	Observed candle power.	Candle power per foot of gas consumed.	Time of burner lighted. M.
Jan. 18	26·9	·650	5	1	1	10	20	·9	49·00	396·88	8·10	30
18	26·9	·650	5	1	2	10	20	1·1	53·75	443·80	8·24	60
18	27·0	·650	5	2	3	10	20	·7	28·00	220·86	7·86	25
18	27·0	·650	5	2	4	10	20	·7	28·50	225·45	7·91	50
18	27·0	·650	5	2	5	10	20	·8	29·75	239·76	8·06	75

(Signed) ALBERT T. HALLOCK, PH.D.,

Chemist N. Y. G. L. Co.

The Mutual Gas Light Company, New York, Dec. 27, 1882.

DATE.	Standard of gas and burner. Bray's U. S. No. 7. Batwing.						Friedr. Siemens' Reg. Burner.					
1882.	Candle power.	Specific gravity.	Gas consm'd per hour.	No. of burners.	No. of experiments.	Duration of test. Min.	No. of observations.	Pressure on burner.	Gas consm'd per hour.	Observed candle power.	Candle power per foot of gas consumed.	Time of burner lighted. M.
Dec. 21	28	·700	5	1	Preliminary test.	10	5	1·25	39·00	269·08	6·90	20
21	28	·700	5	1	1	10	5	1·25	40·00	371·84	9·29	35
21	28	·700	5	1	2	10	5	1·30	40·00	412·72	10·32	50
21	28	·700	5	1	3	10	5	1·45	40·80	413·00	9·88	70
22	28	·700	5	2	Preliminary test.	10	5	1·45	22·40	190·68	8·49	20
22	28	·7.0	5	2	1	10	5	1·50	22·60	198·24	8·77	35
22	28	·700	5	2	2	10	5	1·50	22·60	212·80	9·46	50
22	28	·700	5	2	3	10	5	1·50	22·30	198·84	8·91	70
23	26	·725	5	.....	Preliminary test.	10	5	1·25	11·60	97·86	8·45	20
23	26	·725	5	1	1	10	5	1·00	11·60	97·86	8·45	35
23	26	·725	5	3	2	10	5	0·40	10·30	104·00	9·17	50
23	26	·725	5	3	3	10	5	0·40	10·40	97·86	9·41	70
27	26	·725	5	4	1	10	5	1·8	8·00	69·16	8·64	30
27	26	·725	5	4	2	10	5	1·8	8·00	67·34	8·42	35

The Municipal Gas Light Company of New York, Jan. 4, 1883.

1883.												
Jan. 2	29·9	·653	5	1	1	10	10	3	46·00	407·18	8·85	30
3	29·50	·667	5	1	2	10	10	10	46·56	357·25	7·67	20
3	29·50	·667	5	1	3	10	10	10	46·80	386·15	8·25	50
4	29·37	·670	5	3	4	10	10	10	13·14	111·16	8·46	25
4	29·37	·670	5	3	5	10	10	10	13·20	113·66	8·61	50
4	29·37	·670	5	2	6	10	10	10	24·00	209·99	8·76	25
4	29·37	·670	5	2	7	10	10	10	25·20	227·03	9·01	50

(Signed) W. H. BRADLEY, *Chief Eng'r M. G. L. Co.*

The Metropolitan Gas Light Company, New York, January 22, 1883.

DATE.	Standard of gas and burner. Bray's Special No. 7.						Friedr. Siemens' Reg. Burner.					
1883.	Candle power.	Specific gravity.	Gas consumed per hour.	No. of burners.	No. of experiments.	Duration of test. Min.	No. of observations.	Pressure on burner.	Gas consumed per hour.	Observed candle power.	Candle power per foot of gas consumed.	Time of burner lighted. M.
Jan. 22	23·50	0·547	5	1	1	10	10	0·6	48·90	359·32	7·35	25
22	23·50	0·547	5	1	2	10	10	0·6	49·50	400·91	8·09	50
22	23·50	0·547	5	1	3	10	10	0·6	49·80	370·36	7·48	75
22	23·50	0·547	5	3	4	10	10	0·3	14·00	98·70	7·05	20
22	23·50	0·547	5	3	5	10	10	0·3	14·10	104·58	7·42	40
22	23·50	0·547	5	3	6	10	10	0·3	14·04	104·58	7·45	60

(Signed) HERZOG, *Engineer M. G. L. Co.*

The Harlem Gas Light Company. New York, January 13, 1883.

DATE.	Sugg's standard of gas and burner. Argand holes.						Friedr. Siemens' Reg. Burner.					
1883.	Candle power.	Specific gravity.	Gas consumed per hour.	No. of burners.	No. of experiments.	Duration of test. Min.	No. of observations.	Pressure on burner.	Gas consumed per hour.	Observed candle power.	Candle power per foot of gas consumed.	Time of burner lighted. M.
Jan. 13	19·25	0·510	5	2	1	10	10	1	26·10	208·30	7·98	15
13	19·25	0·510	5	2	2	10	10	1	26·10	208·30	7·98	30
13	19·25	0·510	5	2	3	10	10	1	25·38	209·80	8·26	45
13	19·25	0·510	5	2	4	10	10	1	25·38	209·80	8·26	60
13	19·25	0·510	5	2	5	10	10	1	25·90	210·20	8·18	75
13	19·25	0·510	5	2	6	10	10	1	25·80	209·40	8·12	90

The Manhattan Gas Light Company of New York, December 22, 1883.

DATE.	Sugg's "G" burner. 33-hole Argand.						Friedr. Siemens' Reg. Burner.				
1882.	Candle power.	Specific gravity.	Pressure.	Gas consumed per hour.	Candle power per foot of gas.	No. of tests.	Siemens' burners. No.	Gas consumed per hour.	Candle power.	Candle power per foot of gas.	Time lighted. M.
Dec. 22	25	·44	·55	7	3·57	1	1	51·06	327·	6·4	20
22	25	·44	·55	7	3·57	2	1	51·00	505·8	9·91	50
22	25	·44	·55	7	3·57	3	2	26·80	192·	7·16	
22	25	·44	·55	7	3·57	4	2	27·00	208·8	7·72	
22	25	·44	·55	7	3·57	5	3	13·2	72·3	5·48	15
22	25	·44	·55	7	3·57	6	3	14·28	86·34	6·04	50

THE INTERNATIONAL ELECTRICAL EXHIBITION OF THE FRANKLIN INSTITUTE.

The International Electrical Exhibition, for which the Franklin Institute had been making extensive preparations for many months, was opened, according to the official announcement at noon on Tuesday, September 2, 1884.

The formal proceedings were simple and appropriate. They consisted in an address of welcome, by his honor, Wm. B. Smith, the Mayor of the city, to the representatives of the United States, and representatives of learned societies, of foreign governments, distinguished visitors and invited guests, who were assembled in the large lecture hall. Thence the auditors proceeded to the centre of the south gallery in the main Exhibition Building, where, in the presence of a great concourse of visitors, the President of the INSTITUTE, Mr. Wm. P. Tatham, delivered an appropriate address. The formal proceedings were concluded by his Excellency, Hon. Robert M. Pattison, Governor of the State of Pennsylvania, who, at the close of an admirable address, declared the Exhibition open.

The opening ceremonies were attended by official representatives of the British, French, Belgian, German, Mexican and United States Governments, by representatives of numerous scientific and technical societies, the American Institute of Mining Engineers attending in a body.

Although in some important features the Exhibition was not complete on the opening day, the exertions of the managers to have everything ready in time were well repaid by the generally creditable condition of the exhibits.

At the time of this writing the Exhibition is at its height, and it is proper to say that in every important element that goes to make a notable exhi-

bition, the International Electrical Exhibition has fully realized the hopes and anticipations of the managers of the great undertaking.

The presence and attendance of many members of the British and American Association for the advancement of Science, the Royal Society of Canada, the American Institute of Electrical Engineers, and the meeting of the United States Electrical Conference, which was called into existence through the representations of the officers of the Exhibition, has added greatly to the importance and usefulness of the Electrical Exhibition, in that it has enabled the officers charged with the scientific branch of the work to secure the valuable aid and active participation of many distinguished men of science, on the Board of Examiners having charge of the work of tests and measurements of machines and apparatus. This important work is now in an advanced state, and promises, when finished and published, to take rank as an important contribution to applied electricity.

The direct value of the Exhibition as a means of education has been utilized to the highest possible degree. The Board of Public Education of the City of Philadelphia has directed each of the schools of and above the grade of grammar school within its control, to take a day to visit the Exhibition with its teachers, in lieu of a school session ; and, in response to invitations sent by the officers of the Exhibition to the directors of schools within a radius of one hundred miles, embracing Eastern Pennsylvania, New Jersey, Delaware and Eastern Maryland, a large number of pupils with their teachers have availed themselves of the opportunity of visiting the Exhibition. To assist to an intelligible study of the machinery and apparatus, a series of " Electrical Primers " was prepared, giving in simple and readily comprehensible language, explanations of the principles, construction and operation of the principal groups of exhibits, and placards were posted conspicuously in the neighborhood of characteristic machines, etc., to identify them by name to those to whom they were unfamiliar. The primers, which were issued and sold at a nominal price, proved their usefulness by an enormous sale.

The educational character of the Exhibition was furthermore pronounced by a series of lectures given twice a week in the large lecture hall. These lectures, which were delivered by men of eminence upon topics related directly or indirectly to the subject of Electricity, were listened to by crowded audiences and proved to be highly popular. They will be published in a special volume after the close of the Exhibition.

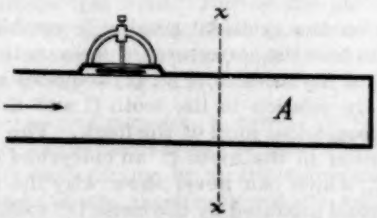
The International Electrical Exhibition, by universal admission, is by far the most valuable and successful (from an educational standpoint) exhibition ever undertaken by private enterprise in the United States, and the officers and members of the Exhibition Committee, through whose earnest, long-continued and well-directed labors the undertaking was carried to a successful issue, are well satisfied with the results of their work. The JOURNAL for November will contain an elaborate historical sketch of the Exhibition by Prof. E. J. Houston, the Electrician of the Exhibition, and a summary of the work of the Board of Examiners, which promises to be of the highest interest, will be given by Prof. M. B. Snyder, Chief of the Board of Examiners. Prof. Snyder will likewise review the work of the United States Electrical Conference. W.

CORRESPONDENCE.

Committee on Publication Franklin Institute.

GENTLEMEN:—Referring to the discussion on "Tests by Hydrostatic Pressure," I beg to say that I do not remember having heard Mr. Nystrom state that my "statement, that the momentum of the water in the connecting pipe can hardly even temporarily increase the pressure in the boiler, is disproved by the operation of the hydraulic ram" (page 121, Aug., 1884). I am so much more surprised at having overheard this remark, as the hydraulic ram was then in my mind, and I would have referred to its relation to my statement if I had not then dismissed the idea that any one of the audience would be thoughtless enough to confound the two cases. In the boiler there is no outlet to the water forced into it, and the additional water increases the pressure *slowly*, because of the elasticity of the walls. If the outlet from the chamber (or termination of the feed-pipe) of a hydraulic ram were *closed*, I fear Mr. Nystrom could not force one drop of water into the same without increasing the pressure very far beyond that due to the impact. Or let Mr. Nystrom make a hydraulic ram using a common ten-horse boiler for the chamber in which the impact is to take effect, I am afraid he would not pump much water.

Let the sketch represent a hydraulic ram without outlet, and I am willing to repeat and defend the statement that the pressure in the space A is a function of the *amount of water* which has been forced beyond the sec-



tion xx, no matter whether that compression was caused by a steady pressure or by a blow. By concussions of the feed-water no boiler under test ever suffered anything beyond what was due to the pressure owing to the amount of water that had been forced into it, except if a number of regular concussions produced vibrations, which may in rare cases have a slight tendency of producing extra strains.

The calculations of Mr. Nystrom showing the alleged pressure resulting from impact are simply another instance of the anomalies at which theorists arrive who leave out of consideration the principal factors of a phenomenon (in this case the friction of water in the pipe is one of the principal causes of retardation). And why should the retarding force $\frac{2LvA}{Ta}$ be an *additional* pressure? Being a retarding force, expressed in pressure per square inch, it can express the *absolute* difference only between the reaction of the boiler and the pressure of water as it enters the force-pump, and not

a pressure over and beyond the hydrostatic pressure in the boiler. That the impact should produce an additional pressure of 168 pounds, or even 10 pounds, when the boiler is not in a condition to offer an additional resistance, of $\frac{1}{10}$ pound (owing to the quantity of water contained in the same), is simply preposterous. If friction is neglected, the formula (7) is correct enough as far as it goes, but P is the hydrostatic pressure in the boiler, and T is the unknown quantity determinable by the formula.

The phenomenon can be compared with the well-known experiment of the athlete carrying an anvil on which a blacksmith is plying his trade.

HUGO BILGRAM.

Book Notices.

A TREATISE ON TOOTHED GEARING. By Howard Cromwell, Ph.B. New York: John Wiley & Sons.

The author, after having "sought often and earnestly, but always in vain, for a terse, compact, yet complete and comprehensive work on the subject of toothed gearing," attempts to supply this want by the present treatise. A careful perusal, however, shows plainly that he has made a failure of it, apparently because he himself is not fully acquainted with the subject on which he writes. The following are some of the more prominent errors:

His explanation on the cycloidal gearing is rambling, to say the least, when he attempts to base the correctness of form on the least possible friction. The point a of the tooth C' (Fig. 12) describes a prolate epicycloid, not a hypocycloid, in relation to the tooth C, and this can therefore not account for the hypocycloidal form of the flank. The point a of the tooth C describes, in relation to the tooth C' an epicycloid described by rolling the circle O on B, which can never show why the face of the tooth C' should be an epicycloid produced by the circle O'' rolling on B. In Fig 12 the first contact between the teeth C and C' takes place on the pitch-point of the tooth C, which is a blunder. He explains that the point a of the one tooth slides along the flank of the other tooth while the point a of the other tooth slides along the face of the first one. If this were correct there would be at least two points of contact between two working teeth after the first contact.

To the all-important subject of interchangeable gearing he devotes fifty-five words which are casually inserted at a place where nobody would look therefor.

The explanation for the correctness of involute gearing is vague, and one of the essential conditions—the constant proportion, in mating gears, between evolute-circle and pitch-circle—is not even mentioned. He uses the bottom of the teeth for the evolute circle; yet in describing the involute rack he mentions the angle of 75° as the proper one. His statement that radial flanks are used in involute gearing is incorrect.

He figures (Fig. 66) a worm working inside an annular worm gear after stating that worm-teeth are drawn as for a rack. If he had made the worm a modification of a Hindley worm, the absurdity would be less profound.

By placing the square wheel of Fig. 100 inside of its mate, it will become evident that the circumferences of both wheels as designed by the author, are *not* equal, as he says they should be.

If a student attempts to get an insight into the theory of gearing by means of this treatise and fails to see how the assertions correspond with the demonstrations, he can certainly not be blamed. There is, indeed, a serious danger that he may become hopelessly confused on the subject of gearing. H. B.

ELECTRIC BOATS.—M. Reckenzaun believes that on boats of moderate dimensions electricity can be advantageously substituted for steam. The motor should always be ready to act and should occupy the least possible space. The duration of action is of little consequence, since the distances to be traversed are generally small. An electric boat can carry twice as many passengers as a steam boat; consequently it can be smaller, cheaper, and less difficult to drive. Electricity has the additional advantage, especially in pleasure boats, of avoiding smoke, smell, noise, and the inconvenient presence of the boiler. It is not long since a steam canoe carrying fuel sufficient for seven hours' consumption was considered a marvel; electric boats already surpass this limit. During the past autumn an electric canoe made numerous voyages on the Danube, under excellent conditions, and there is reason to expect that even ships of considerable size may be finally driven by electricity.—*Chron. Industr.*, Feb. 3, 1884. C.

PERFECT ELASTICITY OF CHEMICAL SOLIDS.—W. Spring has conducted an extensive series of experiments with the view of determining the possibility of permanently diminishing, by means of pressure, the volume occupied by a given weight of any chemically definite solid body. Prismatic sulphur, when freshly prepared, and plastic sulphur, are changed, under great pressure, into the denser variety of octohedric sulphur; in like manner, amorphous arsenic is partially transformed, under adequate pressure, into denser crystalline arsenic; but in each of these cases there is a change of allotropic state accompanying condensation. Spring therefore concluded that matter takes the allotropic condition corresponding to the volume which it is forced to occupy, and his researches confirm this opinion. Solids behave under pressure like liquids and gases, and the specific weight of a body, when it is pure and free from cracks and crevices, has a signification of the same value as the atomic weights of the elements.—*Bull. de l'Acad. Belg.*, 1883. C.

PROTECTION AGAINST BOILER EXPLOSIONS.—Prof. Melsens in 1871 published some interesting experiments upon heating water in contact with metallic surfaces. Boutigny, in his investigations of the spheroidal state, was led to regard it as the principal cause of the fulminating explosions of

steam boilers. Melsens concluded that when the bottom of the boiler is provided with numerous points, the ebullition is produced with ease and the water does not assume the spheroidal state under circumstances in which that phenomenon would be produced in presence of a smooth metallic surface. M. le Blanc invited Prof. Melsens to exhibit his experiments before the "Société d'encouragement pour l'Industrie Nationale." They were very satisfactory and were highly appreciated by all who witnessed them.—*Bull. de la Soc. d'Encour.*, Nov., 1883. C.

PROUT'S LAW.—Marignac, in his late re-examination of some of the atomic weights, considers that Prout's law is only approximate, and that, since the numbers which express the atomic weights only represent ratios, there is no reason for taking the hydrogen unit in preference to 16 or 100; but the choice of 16 is justified by its practical advantage. It allows us to represent the atomic weights of the greatest number of elements, and especially of those which are most important, by the most simple possible integers, and with the least difference from the rigorous results of experiment. The fact that the atomic weights exhibit more exact ratios to the oxygen than to the hydrogen unit was pointed out by Chase in his 138th photodynamic note (Proc. Amer. Phil. Soc., Nov. 4, 1881.)—*Ann. de Chim. et de Phys.*, March, 1884. C.

MANGANESE IN WINE.—Maumené has analyzed three specimens of wine: 1, a red wine of Grave, of the vintage of 1865; 2, a similar wine of 1882; 3, a white wine of 1883. In the first specimen he found manganese under the form of a tartrate of potassa and manganese. The second wine contained a like compound in a slightly different proportion; the same is true of the third specimen. It is to be observed that the lands where the three vineyards were situated belong to a region in which manganese abounds.—*Chron. Industr.*, April 13, 1884. C.

NEW APPLICATIONS OF ELECTROLYSIS.—Two new applications have been lately reported which seem worthy of further trial. The first is a system of tanning, in which the skins are suspended in a tannin bath, which is traversed by an electric current. The skins are at first placed at the negative pole, in order to destroy the nitrogenous matters; after eight days a more concentrated solution is introduced, and the direction of the current is reversed. This is said to oxidize the tannin and to hasten its precipitation in the cells of the hides. In the second application, M. Abadie seeks to recover the tin from the scraps of tinned iron which are so abundant about tinner's shops. He places them in an electrolytic bath formed of a solution of chloride of sodium with the addition of chlorhydric acid. The anode is metallic and the tin is deposited upon it, in crystals if the current is intense, or in an amorphous layer when the current is moderate. The rapidity and thickness of the deposit is said to be proportioned to the acidity of the bath.—*L'Electricien*, March 15, 1884. C.

TRANS-NEPTUNIAN PLANET.—Flammarion has followed the line of investigation which was marked out by Forbes and has published the indications which he has discovered of a probable planet, at the first of the

harmonic distances which was pointed out by Chase (Proc. Amer. Phil. Soc., xiii., 140). He admits that many years will doubtless elapse before the planet can be discovered and followed by the telescope, but he thinks that there is no doubt of its existence and that it will appear like a star of the twelfth magnitude, which is quite large enough to be seen by many of the telescopes which are now in use in astronomical observatories.—*L'Astronomie*, March, 1884. C.

First Balloon Passage from France to England.—M. F. Lhoste made his first attempt to cross the English Channel by balloon, on May 27, 1883. After nearly reaching Dover the currents drove him towards the coast of Holland, and he landed at Wönsdrecht. Subsequent unsuccessful attempts were made on June 5, June 7, July 14, and August 13. Not being discouraged by these successive failures, he made an ascension from Boulogne-sur-mer on September 9, at 5 P. M., and he landed on the English coast at about 11 A. M. on the following day. He communicated an interesting account of his several attempts to Flammarion, which is published in *L'Astronomie* for March, 1884. C.

Oblateness of Uranus.—Prof. Saffarik having called Schiaparelli's attention to the favorable position of Uranus for the study of its figure, the Milanese astronomer examined it with powers of 322, 417, 500, and 690. The disc was very sharp and well defined. From 25 series of observations he deduced 3·91″ for the mean equatorial diameter, and 3·756″ for the polar diameter. This gives an ellepticity of 1 ÷ 10·98, which is almost identical with that of Saturn. These measurements confirm those of Madler and Saffarik.—*L'Astronomie*, March, 1884. C.

Hatching Chickens by Electricity.—An interesting experiment has been successfully tried in Berlin. A basket is provided containing a nest of hay, closed by a well-adjusted covering and provided underneath with a thick pillow, which contains a metallic spiral. A battery of six cells, in a neighboring room, furnishes the electricity for warming the spiral, the current passing through a lever regulator. As the temperature should be kept constant, a small thermometer is inserted, with the bulb in the nest and a fine platinum wire soldered into the tube. When the temperature becomes too high, the mercury touches the wire, forming a contact which throws the apparatus out of circuit. When it cools again the current is restored and the temperature raised.—*La Nature*, May 31, 1884. C.

Tide-Gauges.—The sea level has been generally adopted as the base of geodesic measurements. Of late years automatic instruments have been used for registering the mean level of the ocean at stated epochs. These measurements have been made with the greatest exactness in Holland, where the gauges are under government control. The level of the North Sea does not seem to have varied for a hundred and fifty years. The level of the Baltic is the same as when the first observations were made in 1826. The principal European governments have commissions which are charged wirh these measurements. The French Commission has begun a

very important work, which will surpass in extent everything of the kind that has hitherto been undertaken. In Belgium measurements have been for 8,477 different localities. The leveling, which is now in progress in Holland, though on a narrower scale, is remarkable for its precision. In Germany operations began in 1865 and will probably be completed in 1887. In Russia the work has been in progress since 1873. An interesting point, which will soon be determined, is the difference of level between the Baltic and the Black seas. The Spanish operations have shown that the level of the Atlantic at Santander is 0,582 metres above that of the Mediterranean at Alicant.—*Ann. des Ponts et Chauss.*, March, 1884. C.

IMPORTATION OF AMERICAN GRAPES INTO FRANCE.—Ch. Joly has presented a paper to the *Société d'Horticulture*, upon the importation of muscat grapes from the United States into France. The grapes were preserved in an aqueous solution of glucose. The attention of the grape growers of France and Algiers is invited to the important consequences which may follow this importation. The United States, outside of their enormous grain trade, have hitherto been limited to the export of fruits prepared by a previous drying, which removes about 85 per cent. of the water that they contain; this operation has the double advantage of diminishing the weight to be transported and of facilitating the preservation of the fruit. M. Joly, while calling attention to the danger of an interference with the French grape trade, urges cultivators to increase their production as much as possible, chiefly by the rational amelioration of their methods of culture.—*La. Nature*, May 3, 1884. C.

HYDRODYNAMIC IMITATION OF ELECTRIC PHENOMENA.—Decharme, having imitated, by liquid or gaseous currents, the principal phenomena of static and dynamic electricity, electromagnetism, electrodynamics, induction, electrochemistry, and even electrophysiology, concludes that electric and magnetic phenomena are similar to hydrodynamic phenomena; in other words that electricity, under the form of an æthereal or ponderable current, is analogous to a liquid current, and, when in a state of tension, resembles a quantity of liquid diffusing in a jet. Electric movement is then a true flow and not a mere vibration. Its equipotential lines may be exactly represented by Lamé's differential equation for the curves of hydraulic level. There are some electric phenomena, however, which appear to be the result of vibratory and gyratory movements; but these movements naturally result from the transformation of wave motion in a continuous current.—*Ann. de Chim. et de Phys.*, April, 1884. C.

TREPANNING OYSTERS.—Bauchon Brandely, in order to study the embryonic growth of the oyster, perforated the upper shells by means of a trepan. After the hole is made and the particles of the shell carefully removed a stopper is prepared of linen, wax or some other material, to exclude the water and the enemies of the oyster. The shell is reconstructed by a thin layer of pearl in about eight days. In order to prevent the growth being too rapid while the observations are going on, the stopper is turned around every two or three days.—*Les Mondes*, April 19, 1884. C.

NEW SOURCE OF CAOUTCHOUC.—The attention of the Indian government has lately been drawn to a new plant, common in southern India, which gives an adundant supply of pure caoutchouc. It belongs to the class of the *Apocynaceae*, and is called *Prameria glandulifera;* it is a native of the forests of Cochin China, and its sap is often used medicinally. When the branches are broken, a large quantity of Caoutchouc is seen in the interior, which can be drawn out in threads, as in the *landèlphia* of eastern Africa. The plant can be propagated from young shoots, and M. Pierre, director of the botanical garden of Saigon, thinks that it can be transplanted until it is about ten years old, and that it may constitute an addition of great value to the forest products of India. —*Mon. Scientif.*; *Bull. de la Soc. d'Encour.*, March, 1884. C.

PHOSPHORESCENCE OF THE DIAMOND.—Experiments have lately been made with a diamond of 92 karats, which is one of the finest known outside of royal or national collections. It is of wonderfully pure water and is admirably cut with 64 perfectly geometrical facets. Its value is estimated at $60,000. When exposed during an hour to the rays of the sun it preserved for more than twenty minutes in a dark chamber, a light sufficient to show the white paper which reflected its rays. The same phenomenon was exhibited, but with somewhat less intensity, after having submitted the diamond to a powerful electric light. A very apparent phosphorescence was also produced by rubbing the diamond for a few moments with flannel.—*La. Nature*, May 10, 1884. C.

PURE MAGNESIUM.—Grätzel's patent for the separation of alkaline metals by electrolysis has been very successful in the reduction of magnesium. At a late sitting of the *Electrotechnishe Verein*, in Berlin, a ball of magnesium, of about 15 centimetres diameter, excited general attention. It was of superb brilliancy, similar to that of silver, and had lost nothing of its lustre since its separation by electrolysis. This preservation is a sign of its chemical purity, and forms a remarkable contrast with the magnesium hitherto obtained, which was always more or less affected by potassium, and consequently easily oxidized, especially in a damp atmosphere. Magnesium seems destined to increasing maritime use, for its rays appear to have a greater penetrating power in fogs and mists than those of the electric light.—*Lumiere Electr.*, May 31, 1844. C.

ARTIFICIAL GRAPHITE.—Dr. Aron has exhibited, at the meeting of the Berlin Electrical Society, various specimens of vegetable carbon, which were made conductors and rendered almost incombustible by energetic and prolonged heating, in a vacuum or in a neutral atmosphere. These properties are so much like those of graphite that the product may well be called artificial graphite, although it is not crystalline. The experiments show that if, as has been affirmed, the presence of hydrogen in graphite determines its combustibility, this can be true only of combined hydrogen, for carbon which has been calcined and made incandescent in an atmosphere of hydrogen is no more combustible than before.—*Technologist; Chron. Industr.*, June 1. 1884. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held September* 17, 1884.]

HALL OF THE INSTITUTE, September 17, 1884.

The President, William P. Tatham, in the Chair.

Present, 42 members. New members elected by the Board of Managers at the meeting of July, 12th, 12; at the meeting of August 13th, 19, and at the meeting of September 10th, 16.

The following action from the August Meeting of the Board was reported:

Resolved, That the Board of Managers recommend the election of M. H. TRESCA, Professor at the Conservatoire des Arts et Metiers, in Paris, as an honorary member of the Franklin Institute.

Prof. Tresca was unanimously elected.

The President announced the death of Professor Robert E. Rogers, for many years a member of the Institute, who had served upon many of its committees, and upon the Board of Managers, and who had acceptably filled the offices of Vice-President and President of the Institute. The President announced that the Board had appointed a committee composed of Mr. J. E. Mitchell, Prof. Edwin J. Houston, and Dr. Isaac Norris, to suitably express the sentiments of the Board.

Mr. Mitchell, seconded by the Secretary, moved that a committee of the Institute be appointed to co-operate with the committee appointed by the Board of Managers to prepare a memorial of the deceased. Carried.

The President, thereupon, appointed Dr. Charles M. Cresson, Dr. G. M. Ward, and Dr. William H. Wahl.

Mr. Hugo Bilgram, seconded by the Secretary, moved that the Committee on Meetings be requested to consider the propriety of providing, at such meetings of the Institute, where discussions are likely to take place, a stenographer, to accurately report the same. Mr. Bilgram intimated that the discussion of papers read before the Institute, as they subsequently appeared in the JOURNAL, did not always give the substance of what was spoken, and that he had found it necessary to make reply to printed statements purporting to be the record of a discussion, which statements he was satisfied were an afterthought, and not made at the meeting.

The Secretary, in seconding the motion, stated that for reports of the discussions and debates, he was at present obliged to depend largely upon the courtesy of the participants to obtain abstracts of their remarks for the JOURNAL. He believed that the adoption of the plan proposed by Mr. Bilgram would have many advantages. It would certainly insure greater accuracy in the reports of discussions. The motion was carried.

Adjourned.

WILLIAM H. WAHL, *Secretary.*

LIST OF BOOKS ADDED TO THE LIBRARY FROM JANUARY TO JUNE, 1884.

Agricultural College of Pennsylvania. Memorial. Feb. 24, 1865.
From the College.

Agricultural College of Pennsylvania. Statements made by Dr. E Pugh to Judiciary Committee. Harrisburg
From the College.

Agriculture. Commissioner of. Report for 1883. Washington.
From the Agricultural Department.

Alabama. Geological Survey. Reports of progress for 1875–78 and 1881–82. Montgomery. 1876–79 and 1883. From E. A. Smith State Geologist.

Almanac for 1884. From the *Public Record.*

Almanac for 1884. From the *Philadelphia Inquirer.*

Almanacque Nautico para 1871–77. Cadiz, 1869–76.
From Cecilio Pujazon, Director of Naval Observatory, San Fernando.

Amarican Academy of Medicine. Annual Addresses. 1879–83.
From the Academy.

American Bar Association. Reports of Second to Sixth Annual Meetings. Philadelphia 1879-1883. From the Association.

American Bell Telephone Company, *et. al. vs* The People's Telephone Company, *et al.* From the Company.

American Exchange and Review for 1864–70.
From the Editor, Mr. Fowler.

American Institute of Mining Engineers. Vol. II, 1882–3.
From the Institute.

American Journal of Fabrics and Knit Goods Manufacturer. Vols 3 and 4. 1883–84. From the Publisher.

American Railway Master Mechanics' Association. Report of Proceedings of 16th Annual Convention. Chicago, June, 1883.
From the Association.

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American Society of Mechanical Engineers. List of Members. January 1, 1884. From the Society.

American Society of Mechanical Engineers. Transactions. Vol. 4, 1883.
From the Society.

Anales del Ministerio de Fomento de la Republica Mexicana. Tomo 7. Mexico, 1882

Annales Industrielles. Paris. Missing Plates. From L. S. Ware.

Architectural Drawings. Miscellaneous. A Collection of Plates.

Arkansas and Texas. Plain Facts.

Army Register. January, 1884.
From the Adjutant General's Office, Washington.

Baltimore and Ohio Railroad Co. Fifty-seventh Annual Report of the President and Directors to the Stockholders. 1883.
From the Company.

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From Hon. G. W. Hall, H. R.

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Becker, G. F. Geology of the Comstock Lode and Washoe District. Washington, 1882. Atlas and Text.

Brendlinger, P. F. Foundations for River Bridge Piers.
From Engineers' Society of Western Pennsylvania.

British Journal. Photographic Almanac for 1884. From the Publisher.

Brüll, M. A. Mémoire sur la chaine flottante des Mines de Fer de Dicido. Paris, 1884.

Buffalo City Water Works. Fifteenth Annual Report for 1883.
From the Chief Engineer, Buffalo, N. Y.

Building Material. Mechanical Tests of. Made August 1882 and November 1883. Philadelphia, 1884.
From Samuel C. Perkins, Pres. of Public Building Commissioners.

Bureau of Education. Circular of Information, No. 4, 1883, and Education in Italy and Greece. Washington. Government, 1883.
From the Bureau.

Bureau of Education. Report of Director of American School of Classical Studies at Athens for 1882-83. Circular of Information, No. 1, 1884. Washington, 1884. From the Bureau.

Bureau of Education. The Bufalini Prize. Washington 1883.

Bureau of Statistics. Treasury Department, U. S. Annual Report of the Chief on Commerce and Navigation for 1883. Washington.
From the Chief.

Bureau of Statistics. Treasury Department, U. S. Nos. 1 and 2, 1883-84. Quarterly Report of the Chief. Washington, 1884. From the Bureau.

Bureau of Steam Engineering. Annual Report of the Chief for the years 1882 and 1883. Washington. From the Bureau.

California. First Annual Catalogue of the State Museum, 1881, and Second and Third Reports of the State Mineralogist, 1880-83.
From H. G. Hanks, State Mineralogist.

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Chicago Historical Society. Collection. Vols. 2 and 3.
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Commissioner of Fisheries of the State of Pennsylvania. Report for 1881 and 1882. Harrisburg, 1882. From the Commissioners.

Connecticut Agricultural Experiment Station. Annual Report for 1883. New Haven. From the State.

Concord, N. H. Twelfth Annual Report of the Board of Water Commissioners for 1883. From the Commissioners.

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